

CHEMICALS IN FISH

REPORT NO. 1

**CONSUMPTION OF FISH AND SHELLFISH IN CALIFORNIA
AND THE UNITED STATES**

FINAL DRAFT REPORT

July 1997

Pesticide and Environmental Toxicology Section
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

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PREFACE

This report represents the first in a series of documents that are being prepared by a technical team of staff in the Pesticide and Environmental Toxicology Section of the Office of Environmental Health Hazard Assessment (OEHHA). This series of guidance documents and reports is being developed to address questions and issues that continuously arise for scientists in agencies and programs which are charged with protecting human health and aquatic resources. Common issues pertain to chemical contaminants in fish and shellfish. The series will address these contaminants from a human health perspective, which is central to OEHHA's role of issuing sport fish consumption advisories for the State of California.

The designated lead scientist (author) for each report conducts the majority of the research and prepares the document with continuous input and review by other members of the team. The team consists of the following members: Robert K. Brodberg, Ph.D.; Joseph P. Brown, Ph.D.; Anna M. Fan, Ph.D.; Margy Gassel, Ph.D.; Gerald A. Pollock, Ph.D.; and Hanafi Russell.

OEHHA is a department of the California Environmental Protection Agency (Cal/EPA). Its charter is to support the agency's mission of improving environmental quality and protecting the public health, the welfare of our citizens, and California's natural resources. OEHHA provides scientific leadership consistent with the principles of sound risk assessment. OEHHA's responsibilities include:

- Assessing health risks to the public from pesticide and other chemical contamination of food, seafood, drinking water, and consumer products, and developing health-protective exposure standards to recommend to regulatory departments; and
- Making recommendations to the California Department of Fish and Game and the State Water Resources Control Board with respect to sport and commercial fishing in areas where fish may be contaminated.

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I. EXECUTIVE SUMMARY

Human consumption of chemically contaminated fish and shellfish poses a potential health risk, the magnitude of which depends on the amount of fish consumed and the degree of contamination. Evaluation of the potential risks to populations that may be exposed to chemically contaminated fish and/or shellfish requires a knowledge of the patterns and rates of fish consumption by these populations. Additionally, fish consumption rates are used in the development of water quality criteria. Therefore, reliable estimates of fish consumption rates are essential to agencies and programs which have responsibilities in the protection of human health and aquatic resources.

In order to characterize human exposure to contaminated fish and shellfish, the potentially exposed population must be identified, and the likely types and quantities of fish and shellfish consumed must be determined. Historically, a variety of fish and shellfish consumption rates have been reported and used by different researchers and agencies. However, the consumption rates that have been determined may not be representative of local populations, and data which describe local consumption patterns and population characteristics for the population of concern may not be available or feasible to collect. Thus, exposure assessments often have to rely on rates reported in existing studies conducted in other regions and/or for other purposes. Estimates of consumption rates that describe fish and shellfish consumption for a particular population(s) of concern must be derived from the most reliable studies and from those that are most applicable to the population(s) of interest.

When selecting the most appropriate estimates of fish and shellfish consumption, it is essential to identify the purpose and use of the estimated fish consumption rates. In order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption rates that apply to people who actually consume the fish and/or shellfish should be used. If consumption rates are to be used to develop water quality criteria, estimates which apply to the consumption of fish and/or shellfish from the water body of concern are appropriate. Per capita consumption rates derived for the general population (including nonconsumers) would not be appropriate for determining potential health risks to consumers from consumption of contaminated fish or shellfish and thus are not applicable to the development of water quality criteria for local water bodies. In addition, when fish consumption rates are to be used to conduct an exposure assessment for locally abundant pollutants only, consumption rates that apply to consumption of fish and/or shellfish from the affected water bodies should be used. In contrast, if the chemical(s) of concern is one with a more global distribution, such as methylmercury, then estimates of total fish consumption from all sources, including commercial and sport fish, are required to evaluate potential risks from exposure to this chemical via ingestion of fish and/or shellfish.

In this report, broad definitions of “fish and shellfish” will be used. The term “seafood” is considered here to include any edible organism from any water body. It generally is synonymous

with the phrase “fish and shellfish” which is used throughout the report to denote any type of edible aquatic animal, excluding marine mammals. “Fish” includes any of various aquatic vertebrate animals having gills and commonly fins, including the bony fishes (those having bony skeletons) and more primitive forms with cartilaginous skeletons (such as sharks and rays). “Shellfish” includes any edible invertebrate animal usually belonging to one of the following taxonomic categories: 1) mollusks, including bivalves, gastropods, and cephalopods; 2) crustaceans; and 3) echinoderms. However, it should be noted that consistency among studies is lacking in terms of which types of seafood were actually included in the study. Therefore, estimates of consumption of fish and particularly shellfish across studies may not (and likely will not) include the same types of organisms.

Per capita consumption rates are estimates derived for the general population inclusive of both consumers and nonconsumers. Thus, per capita rates are primarily useful for trend analyses rather than representing actual consumption. Average per capita rates derived from national surveys for consumption of fish and shellfish by the general population ranged from 12 to 17.9 g/day. Several analyses of data used to estimate per capita consumption of fish and shellfish have found an increase of approximately 25 percent between 1970 and the early 1990’s, indicating that the U.S. population as a whole consumed more fish in more recent years.

“Consumer only” consumption rates are preferable to per capita rates for use in describing actual consumption of fish and shellfish in the U.S. The only overall national mean rate currently published and applicable to all consumers of fish and shellfish combined is 48 g/day. This value may be a minimum estimate as it does not include fish and shellfish in mixed dishes. Additionally, this value was derived from a study conducted nearly twenty years ago, in the mid-1970’s. Unpublished results from a more recent national survey determined an estimated mean rate of 100 g/day for consumers of fish and/or shellfish including mixed dishes. However, data for “consumers only” from national surveys are limited because the reporting period typically covered only three days, and frequency of consumption was not determined. Therefore, the results may not characterize long-term consumption rates for consumers. Additionally, national studies that have been conducted thus far were not intended to address consumption of sport fish and shellfish. Thus, the results of these surveys are applicable mainly to consumption of commercial fish and shellfish and are not suitable for characterizing consumption by fishers or other consumers of sport fish and shellfish.

Regional studies of sport fishing populations reported overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 g/day. These studies can be used to derive estimates of sport fish and shellfish consumption for populations in regions where geographic and population characteristics are similar, provided that the limitations of a given study are considered and a range or distribution of consumption rates is used (including at least the median, mean, and an upper percentile rate) to represent the population as a whole. The overall mean rates for total fish consumption calculated from the studies that targeted fishing populations (and reported on consumption of both sport and commercial fish and shellfish) ranged from 16.1 to 61.3 g/day.

These studies indicated that sport fishers consumed commercially available species in addition to sport-caught fish and shellfish.

The United States Environmental Protection Agency (U.S. EPA) developed and has advocated a fish consumption rate of 6.5 g/day^a for the general population for consumption of fish and shellfish from estuarine and freshwaters. The 6.5 g/day default value has subsequently been adopted by other agencies and has been applied in innumerable instances inappropriately, without an adequate understanding of its derivation and applicability. Consequently, the widespread use of 6.5 g/day as a default value for fish consumption in general, and particularly for sport fishers, has been unjustified and inappropriate. The 6.5 g/day value was initially derived from data on fish and shellfish consumption obtained from a national survey conducted in the early 1970's. This estimate was based on consumption of nonmarine (freshwater and estuarine) species only, and was determined on a per capita basis although only about 14 percent of the U.S. population reported consumption of nonmarine fish in the survey. Additionally, the distinction between sport-caught and commercially purchased fish and shellfish was not maintained in the original compilation of data, and consumption rates for commercial and noncommercial fish and shellfish could not be differentiated. Therefore, the use of this per capita estimate as a default value to represent actual consumption by consumers of sport fish and/or to derive water quality criteria which are intended to protect consumers of fish obtained from these water bodies is indefensible.

Difficulties in defining and evaluating subsistence fishers have resulted in limited information pertaining to consumption rates for subsistence populations. A few distributional datasets are currently available for sport fishing populations believed to represent or include subsistence fishers (*e.g.*, Native Americans, some Asian populations, and low income urban populations). Use of an upper level intake rate (such as the 95th percentile) from these distributions in exposure assessments would encompass consumption rates for individuals reporting above-average consumption within these populations and may account for consumption by subsistence fishers. However, in locations where exceptionally high consumption by subsistence populations or other people is expected, obtaining data for the subpopulation of interest would be preferable.

Consumption rates can vary among subpopulations by race or ethnicity, age, sex, income, fishing mode, region of the country, and other demographic variables. A number of studies have demonstrated trends in higher rates of fish consumption for certain racial or ethnic subpopulations. These studies showed that fish consumption rates were higher for some Asian populations, Blacks, Native Americans, and other minority groups. Higher-consuming ethnic subpopulations and other high-end consumers are likely to be represented by upper percentile consumption rates (such as the 95th percentile) derived from a distributional analysis. Some studies also found differences in the patterns of fish consumption and fishing behavior among subpopulations.

^a However, U.S. EPA (1995b) has noted that they are currently evaluating the use of this value and other recommended consumption rates.

Studies that differentiated fish consumption rates (in g/day) by age and sex showed that, generally, males consumed more than females, and the amount of fish consumed increased with age. In many cases, although not all, these differences are likely to correspond to differences in body weight. Exposure assessments should consider body weight as a parameter and use sex and age-specific consumption rates, when available, or adjust for differences in body weight when evaluating subsets of the population. Additionally, there is limited evidence that some elderly fishers consume fish and/or shellfish at rates that exceed (by two to three times) the average for adult sport fish consumers. In the absence of actual data, higher consuming subgroups are likely to be included within the upper percentile consumption rates derived from a distributional analysis.

The available data suggest that consumption rates for sport-caught marine and estuarine fish tend to be comparable to those for sport-caught freshwater fish. Additional data are needed to evaluate the potential for differences in consumption of fish obtained from water bodies in specific regions of the U.S. where variables such as access and availability of fish and/or shellfish may differ substantially.

The Santa Monica Bay Seafood Consumption Study provides the best available dataset for estimating consumption of sport fish and shellfish in California. Additionally, the distribution of consumption rates derived from the Santa Monica Bay dataset can be used as default values when locally specific data are not available (or appear to be inadequate). Consumption of sport fish by populations in California can be described by the consumption rates determined from this study of 21 g/day, 50 g/day, 107 g/day, and 161 g/day for the median, mean, 90th, and 95th percentile rates, respectively. These estimates of fish and shellfish consumption were derived from a study of fishers using a marine water body. However, the similarity between this dataset and that derived for fishers using freshwater bodies (in Michigan) suggests that these default values are applicable to sport fish consumers regardless of whether the fish and shellfish were obtained from marine, estuarine, or freshwater sources.

Studies that specifically address consumption rates for commercial fish and shellfish in California are lacking, although several analyses of national data have indicated that people in the Pacific region consumed slightly more, on average (and per capita), than the overall U.S. population. Therefore, national estimates for consumers (particularly those derived from the most current studies, once the results are available) can be used to approximate consumption by the general population in California that consumes only commercial species. Additionally, because several studies have indicated that total fish consumption by fishers is greater than sport fish consumption (fishers supplement their catch with commercially available species), estimates for sport fish consumers should be increased to account for supplemental consumption of commercial species, or total consumption, by sport fishing populations in California. Limited data suggest that the difference in amount between sport and total consumption ranges from approximately 8 to 42 g/day.

Insufficient data are available to estimate consumption rates for shellfish, although several studies have shown that shellfish and other invertebrate species were among the most commonly caught species by sport fishers, particularly in certain areas including the Pacific region. The rates derived for sport fish consumption by fishing populations in California can reasonably be applied to consumption of shellfish species by those people who catch shellfish as opposed to finfish.

Although reliable estimates of portion size are essential to deriving accurate estimates of consumption rates, data on actual meal size are limited. Assumptions about portion sizes are inconsistent among fish and shellfish consumption studies, but typically ranged from four to eight ounces of fish and/or shellfish per meal. Actual mean meal or portion sizes, when reported, usually ranged from four to eight ounces.

Exposure within a population can best be described by distributional analyses rather than a single point estimate of fish consumption rates. Using a stochastic analysis or at least the median, mean, and an upper percentile rate of intake derived from a distributional analysis will allow a better characterization of consumption in a population and the variability within that population.

Studies on fish and shellfish consumption continue to be performed and released. New information that is pertinent should be considered along with this report as it becomes available.

II. INTRODUCTION

Chemical contamination of fish and shellfish from marine, estuarine, and freshwater bodies has been reported in the literature for various regions of the United States. Water bodies are among the ultimate repositories of pollutants released from human activities as well as from natural sources of potentially toxic materials. Once chemical contaminants reach water bodies, they may concentrate through aquatic food chains and bioaccumulate in fish and shellfish tissues. Human consumption of chemically contaminated fish and shellfish poses a potential health risk, the magnitude of which depends on the amount of fish consumed and the degree of contamination.

For health protection, many states have issued health advisories to recommend restricted consumption of chemically contaminated sport-caught fish and shellfish species from specified water bodies. Evaluation of the potential risks to the populations that may be exposed to chemically contaminated fish and/or shellfish requires a knowledge of the patterns and rates of fish and shellfish consumption by these populations. Additionally, fish consumption rates are used in the development of water quality criteria (U.S. EPA, 1989a; Ruffle et al., 1994; Ebert et al., 1994). Therefore, reliable estimates of fish consumption rates are essential to agencies and programs which have responsibilities in the protection of human health and aquatic resources.

In order to characterize human exposure to contaminated fish and shellfish, the potentially exposed population must be identified, and the likely types and quantities of fish and shellfish consumed must be determined, as well as the concentrations of contaminants in fish and shellfish tissues that are consumed. For estimating the health risk associated with the consumption of contaminated fish and shellfish tissue for the general population or any particular subpopulation (such as children or pregnant women), it is necessary to determine a consumption rate that accurately reflects that population or subpopulation. A number of factors make establishing a consumption rate difficult. These factors should be recognized when evaluating data to derive representative consumption rates for populations of interest.

Historically, a variety of fish and shellfish consumption rates have been reported and used by different researchers and agencies. In recently issued guidance materials, the United States Environmental Protection Agency (U.S. EPA) recommended using or collecting data on local consumption patterns and population characteristics to estimate consumption rates for the population of concern (U.S. EPA, 1994, 1995a). However, locally applicable data may not be available and it may not be feasible to collect them. Thus, exposure assessments often have to rely on rates reported in existing studies conducted in other regions and/or for other purposes. The question arises as to whether default values can be derived from these studies that would be reasonably representative of the population(s) of interest. Guidelines for comparing or evaluating different types of studies or datasets for application to defined specific or general populations are lacking.

The purpose of this report is to summarize and evaluate the available literature that describes fish and shellfish consumption for the general population, for consumers, and for those who catch and

consume sport fish and/or shellfish, and to describe the potential sources of variability in reported fish consumption rates. This comprehensive review is intended to provide a single concise resource that not only summarizes the results of fish and shellfish consumption studies, but also facilitates distinguishing the most appropriate and reliable studies. It includes information that will help to clarify confusion regarding different fish consumption rates that have been cited or used by different individuals or groups. This report is meant to have a broad application and to be used as a reference by different state programs in California and other states in the U.S. The information can be used by agencies and programs which have responsibilities in the protection of human health and aquatic resources, as well as anyone interested in understanding, or in conducting further studies of, fish and shellfish consumption. As studies on fish and shellfish consumption continue to be conducted and released, new information that is pertinent should be considered along with this report as it becomes available.

In this report, broad definitions of “fish and shellfish” will be adopted in an attempt to be all-inclusive and encompass whatever organisms may have been included in any particular study. “Fish” includes any of various aquatic animals (belonging to the subphylum Vertebrata) having gills, commonly fins, and bodies usually but not always covered by scales, including the bony fishes (those having bony skeletons) and more primitive forms with cartilaginous skeletons (*i.e.*, lampreys; hagfishes; and sharks, skates, and rays). The term “sport fish” will be used throughout this report to denote fish that are caught by a sport fisher as opposed to purchased or caught commercially. Synonymous terms (*e.g.*, sport-caught, self-caught, recreationally caught, and noncommercial fish) may be used in some cases, such as when a report or study is reviewed and the authors have used one of these terms. “Shellfish” includes any edible invertebrate animal usually belonging to one of the following taxonomic categories: 1) mollusks, including bivalves (*e.g.*, clams, oysters, mussels, scallops), gastropods (*e.g.*, snails, limpets, abalone), and cephalopods (*e.g.*, squid and octopods); 2) crustaceans (*e.g.*, crabs, shrimps, lobsters); and 3) echinoderms (*e.g.*, sea urchins and sea cucumbers). The term “seafood” is considered here to include any edible organism from any water body. However, it generally is used synonymously with the phrase “fish and shellfish” which would exclude marine mammals and edible marine plants. It should be noted that consistency among studies is lacking in terms of how fish and shellfish were defined and which types of seafood were actually included in a given study. Therefore, estimates of consumption of fish and shellfish across studies may not (and likely will not) include the same types of organisms.

As discussed in further detail throughout this report, consumption rates have been determined for different segments of the population. “General population” refers to the national population as a whole, and includes both consumers and nonconsumers. Estimates of consumption rates for the general population are derived on a “per capita” basis. Consumption rates can also be determined for subpopulations such as “consumers only” or groups of people with particular demographic traits in common. Consumption rates determined for actual consumers may include consumption of either commercial species, sport-caught fish and shellfish, or a combination of fish and shellfish from any source.

In addition to providing a general review and evaluation of the available information pertaining to fish and shellfish consumption, this report will address more specific objectives. The overall objectives are as follows.

- 1) Determine fish and shellfish consumption rates that are appropriate for use in describing the general population, consumers only, and those people who catch and/or consume sport fish and/or shellfish.
- 2) Determine whether default values that have been used historically to represent consumption rates of fish and shellfish, such as 6.5 g/day, a value proposed by U.S. EPA (and subsequently adopted by many agencies), provide accurate and reliable estimates for characterizing consumption by the populations for which they have been used.
- 3) Describe the population of fishers referred to as “subsistence” fishers and determine whether subsistence fishers are included in estimated rates of consumption. Are there studies that included data on subsistence fishers? If so, do these data indicate that upper percentile rates are representative of subsistence fishers? If consumption rates can be recommended that will adequately address subsistence fishers, as well as all other types of high-end consumers, then the risk communication process can be used to enhance the protection of specific at-risk subpopulations by providing information targeted to them.
- 4) Determine whether consumption rates differ among ethnic groups. Do the available data support using different consumption rates for specific ethnic populations? If there are differences, are they consistent across studies, and how different might various subgroups be? Will a rate for high-end consumers adequately represent ethnic subpopulations?
- 5) Evaluate whether the available data indicate differences in rates or patterns of fish and shellfish consumption for groups that differ by age, sex, or geographic location.
- 6) Determine whether the available data support using different rates of consumption for fish and shellfish obtained from different types of water bodies. Do the available data indicate that a population of fishers using a freshwater source has a significantly different distribution of consumption rates than a population using a marine water body?

In addition to meeting the specific objectives listed above, which may apply to populations across the U.S., this report will also focus particularly on consumption of fish and shellfish by populations in California, as follows:

- 7) Describe the consumption of locally caught sport fish and shellfish in California. This description will principally cover the population of sport fishers who catch and consume fish and shellfish, but may also include people who receive and eat locally caught sport fish, such as family members. To describe consumption for California populations consuming locally caught

fish and shellfish, the mean, median, and an upper percentile value (*e.g.*, 90th and/or 95th%) will be used.

8) Describe the consumption of commercial fish and shellfish for sport fishers and for people in California who consume only commercial species. For the purpose of conducting exposure assessments of chemical contaminants restricted to local waters, the description provided by the previous objective would be sufficient. However, in some cases, exposure assessors may need to consider potential exposure to more global contaminants such as methylmercury. For this reason, a description of consumption of fish and shellfish by California populations should include consumption rates of commercial fish and shellfish for those who consume only commercial species and for sport fishers who also consume commercial fish and/or shellfish.

9) Determine whether there are data to describe the portion of the population in California that consumes shellfish, and (if possible) estimate the rate of consumption of commercial and noncommercial shellfish by this population.

In order to address each of the objectives described above, consumption studies that are determined to be most applicable and relevant to the question(s) being considered will be identified, and conclusions will be drawn based on the available information.

The following section of this report briefly reviews factors to consider when comparing results from different studies and surveys. Subsequent sections of the document describe and present findings from various fish and shellfish consumption studies. The reliability and applicability of available data for quantifying fish and shellfish consumption for populations in the U.S. and California will be considered. A discussion section will follow in which the issues identified in the stated objectives of the report will be addressed. And finally, the conclusions of the report will be presented. A glossary of terms is provided in Appendix I. If the author(s) of a specific paper or report use a term to mean something different than what is noted in the glossary, the author's terminology and definition will be provided as part of the description of the study.

III. SOURCES OF VARIABILITY IN FISH AND SHELLFISH CONSUMPTION ESTIMATES

Different fish consumption rates have been reported and used by numerous researchers and agencies. Differences in reported rates may result from a variety of factors including both major and minor differences in study design and in the analysis of the data collected in various surveys. When information for a specific local population is not readily available, the exposure assessor is forced to choose reasonable surrogate populations and default values from applicable studies (if available) that include information on the parameters or variables of interest. Thus the exposure assessor must be able to discern which studies are most applicable and which ones provide the most reliable and accurate information. The results of a given survey are most accurate when the calculated mean is close to the true value and most precise when the variance is small (Anderson, 1988).

Numerous types of surveys and methods for collecting data have been used to estimate fish consumption rates. Each survey methodology has certain inherent biases which can contribute to the variable results seen among surveys. Each survey that has been conducted has strengths and limitations that must be considered when evaluating the rates derived by the study (Ebert et al., 1994; U.S. EPA, 1991). Decisions that are made in the initial stages of planning a study will influence the nature of the findings of the study. The choices that independent researchers and various agencies make about the structure of the planned study are not necessarily consistent. The objectives of each study may vary, the resources available to conduct the study may be limited, and a variety of other factors may influence decisions about study design. When reviewing the various studies and their results, one must evaluate how a given study approached study design and data analysis, and determine whether the approach chosen is applicable to the questions being addressed. Knowledge of the purposes of a study, how the study was conducted, and how the data were evaluated can be used to assess the reliability of the results, as well as to determine how the information provided by the study can be used and whether the results are applicable to a particular scenario of interest.

A. Target populations and characteristics of populations

Different rates of fish consumption have been reported for different population groups. One must first define exactly which group is intended as the target population and then evaluate whether the sample population defined by the study adequately represents the target population (Anderson, 1986). A random probability sample can be used to sample a portion of the target population in a way that the results are applicable to the entire population(s) of interest. However, not all studies have used random sampling methods and in some cases, the sample design does not allow for statistical evaluation of the data.

Rates reported for the general national population, usually referred to as per capita rates, differ from those reported for subpopulations such as individuals who catch and consume their own catch of fish and shellfish. It is essential to consider whether rates that apply on a per capita basis are appropriate to the study question or whether rates specific to particular subpopulations are needed. For example, some consumption rates have been derived by averaging over both consumers and nonconsumers, as compared to consumers only. These per capita estimates would not be representative of consumption by actual consumers or other specific subpopulations. Thus, exposure assessments and evaluation of potential risks to consumers must consider consumption rates for consumers only.

However, in some circumstances it is desirable to describe population-wide risks. For example, when comparing the effects of chemical emissions from facilities across regions, population-wide risks may be estimated and used to rank facilities. In these cases, it may be appropriate to consider the full distribution of consumption for the population residing in the vicinity of the discharging facility. Both consumers and nonconsumers would thus be included in the distribution, and one would expect consumption rates for the lower percentiles to be zero,

reflecting the portion of the population that does not consume sport fish. It is important to recognize the difference between characterizing the whole population and estimating exposure to contaminants in sport fish and shellfish by actual consumers. Often the portion of a population that consumes sport fish is relatively small and these consumers are represented by the upper percentiles in a full distribution. Therefore, using either per capita estimates or a consumption rate derived from a low percentile of the consumption distribution will not accurately estimate exposure to consumers from contaminants in sport fish. As a result, consumption rates that pertain specifically to consumers and which represent a sufficient percentage of the subpopulation that consumes sport fish and shellfish must be used in exposure assessments and consequent management actions (such as the development of water quality criteria) in order to accurately describe exposure to the subpopulation of consumers (as opposed to the general population) and to provide for adequate protection of public health.

For groups of individuals who consume sport fish and/or shellfish, there is a continuum ranging from intermittent fishers, who may eat fish only occasionally, to those who fish regularly and/or heavily and consume large quantities of the fish that they catch. These “high-end consumers” could include recreational fishers with high rates of success and subsistence fishers who rely on their catch to feed themselves and their families. Therefore, within the subset of the general population that fishes (*i.e.*, fishers) there is likely to be a wide range of fishing effort and success, and a single value is unlikely to adequately describe consumption by the entire fishing population.

To obtain estimates of consumption rates for specific subpopulations, such as particular ethnic groups or women of reproductive age, the sample population must include sufficient numbers of people that represent the subpopulation. Often, however, sample sizes are too small to adequately represent these subpopulations and/or to allow statistical analysis of the data.

U.S. EPA (1995a) has suggested that fish consumption data be collected which include descriptive demographic information on the size and location of fishing populations using specific water bodies; ages, sex, and race of those consuming fish and shellfish; size and frequency of meals; types of fish caught; portions of fish consumed; and methods of fish preparation and preservation. Unfortunately, most studies do not characterize the fishing population in the detail suggested.

B. Definitions and terminology

Definitions of relevant terms, *i.e.*, “seafood” and “shellfish” (and sometimes “fish”) can be highly variable, making comparisons of the results of consumption studies difficult. Many studies have been conducted on seafood consumption, however, each one is likely to define “seafood” differently and to include measures of different types of organisms. Therefore, estimates of consumption of fish and particularly shellfish across studies may not (and likely will not) include the same types of organisms.

The term “seafood” can specifically refer only to organisms from saltwater bodies or can include edible items from any type of water body. The term “fish” is usually used to represent finfish only; however, it is used in some cases as a general term which also includes shellfish and/or other types of edible seafood. The definitions of “shellfish” are particularly problematic. The term generally refers to aquatic invertebrate organisms that have a shell. Although certain organisms such as clams and oysters are easily identified as having a shell, other aquatic animals have evolved such that the shell has become internal and/or reduced (*e.g.*, in squid), or has disappeared entirely (*e.g.*, octopus). Crustaceans, including several types that are commonly consumed (*e.g.*, crab, shrimps, and lobster), have exoskeletons which serve as a shell or protective covering. Definitions of shellfish in the literature may be limited to only a few types of edible species or may be more comprehensive. A few studies of consumption of “fish and shellfish” have included species which are less commonly recognized as “shellfish” (*e.g.*, squid and octopus or sea urchins).

In addition, some consumers obtain and eat other types of aquatic organisms such as seaweed (plants) or roe (eggs) from fish or urchins. Some populations in the world also consume certain types of marine mammals. Some of these less common types of seafood may be important in the diet of certain fishing communities and/or ethnic groups. Clearly there is a need to increase consistency in defining terms and, at the same time, definitions need to adequately distinguish which organisms are included. Additionally, definitions are needed which are comprehensive enough to include all types of aquatic organisms that are consumed.

Total seafood consumption by individuals is likely to include fish and/or shellfish obtained from a variety of sources. However, rates may or may not be based on fish and shellfish obtained from all sources including sport-caught, commercial, gift, and fish and shellfish consumed in restaurants. Additionally, studies that derive rates based on all potential sources of fish and/or shellfish may or may not differentiate the sources. Many studies have not included sport fish and of those studies which did evaluate consumption of sport fish, some may have only considered consumption of fish caught from a specific single water body whereas other studies determined rates for fish from multiple water bodies. Ebert et al. (1994) summarized these differences and the contribution they can make to variability in reported rates, as follows. “Because total consumption by an individual is comprised of the sum of the rates of consumption for each of these components, estimates may vary substantially, depending upon which components have been evaluated.”

Consumption rates reported in different studies may or may not differentiate between consumption of marine, estuarine, and freshwater fish and shellfish. Additionally, researchers typically define and use these terms in different ways, resulting in different interpretations of data sets and variations in estimated rates of consumption (Stephan, 1980). Studies may differentiate between marine and freshwater species, but the differentiation between marine and estuarine species is often not clear. Some studies combine estuarine with freshwater whereas other studies combine estuarine with marine species. Further problems can arise in the analysis of data

because distinctions between marine and freshwater species of fish are not always clearly documented in the datasets.

Surveys vary with respect to the number of types of fish or fish products included and how each fish item is defined. Differences in definitions, the way fish items are grouped, omission of certain types of fish products, and how portion sizes are measured or estimated, can influence estimates of the amounts and type of fish consumed and, therefore, can impact the calculated population mean and variance used to estimate consumption rates. Additionally, quantities of fish and shellfish items consumed in food mixtures (“mixed dishes”) such as casseroles or soups and chowders are often difficult to estimate and may not be included in the overall derived rates (USDA, 1983).

C. Types of data and methods of collection

Approaches to collecting data on fish consumption include both indirect and direct measures. Indirect measures primarily rely on data pertaining to food supply availability or food disappearance into marketing channels or households and are best regarded as a measure of food availability into commercial markets and only a rough indicator of consumption. Data from studies on food availability generally have been collected for purposes other than to estimate consumption rates, and data gaps are most serious at the level of the individual consumer; therefore, these types of data are inappropriate for estimating consumption rates for consumers (Anderson, 1986; U.S. EPA, 1992). Additionally, food availability data do not account for waste or spoilage, and interpretation of the results is highly specialized; however, the results from these types of surveys can be useful to assess trends over time (Anderson, 1986).

Direct measures refer to data collected by a variety of methods to quantify actual food use or food consumed by individuals and/or households. There are two types of data that are obtained from these methods: quantitative data and food frequency data (Anderson, 1986). Quantitative data are derived from measures that attempt to obtain exact quantities of food consumed per unit time. However, accuracy in estimating consumed portions may vary among studies. Quantitative data, which are typically obtained over short time periods, are not considered the best measure of usual intake by the individual consumer over long periods of time (Anderson, 1986; U.S. EPA, 1989a).

Food frequency data are obtained from questionnaires about typical patterns of food intake and, thus, are thought to represent usual intake over time. However, food frequency questionnaires are designed to rank or categorize food items rather than to obtain actual measures of intake. Therefore, these data may be less accurate (and less precise) depending on how the amount of food consumed is quantified. This type of survey is also subject to errors in under- or over-reporting, and food frequency questionnaires tend to suffer from loss of exactness in the identification of specific food items in order to achieve improved estimates of usual consumption patterns of foods (Anderson, 1986, 1988).

Fish consumption rates have also been derived based on data obtained through creel surveys. These surveys usually involve contacting fishers to provide water body-specific data about fishing frequency, and fish species and sizes caught and/or consumed. Thus the catch data may only be representative of specific seasons or targeted species. Information derived from creel surveys is often used for fisheries management development purposes, such as to determine fishing activity patterns or demands on specific water bodies, or to evaluate stocking programs for specified lakes and streams. Consumption rates are often estimated from catch data using assumptions of total edible weight represented by the catch, based on the length of the fish, divided by the number of household consumers expected to share the catch (Landolt, 1985, 1987; SDCDHS, 1990; Puffer et al., 1982). Additional assumptions may be made. For example, the amount of fish caught may be estimated when actual measurements of fish catch lengths have not been made or recorded, and estimates of fishing success at nonsurvey times are often incorporated into the calculations of consumption rates (*e.g.*, Puffer et al., 1982; SDCDHS, 1990; ChemRisk, 1992).

Price et al. (1994) suggested that creel surveys may oversample frequent fishers and produce a distribution that overestimates intake rates of the total fishing population using surveyed water bodies. U.S. EPA (1995a) also suggested that creel surveys may be subject to reporting biases in that poor catches or catches below legal size limits or above total limits may not be reported.

D. Time factors

Food intake surveys may only cover specific time periods or seasons. Short-term quantitative recall methods (*e.g.*, a 24-hour food recall to gather information on foods consumed by individuals in the prior 24 hours) can be useful in providing information on total consumption over the specified recall period. However, extrapolation of this information to derive long-term intake rates will contribute uncertainty given the inherent intra-individual variation of intake from day to day.

To reduce intra-individual variability and derive more accurate estimates of individual consumption, use of multiple days of dietary intake data is generally more desirable (Anderson, 1986; Popkin et al., 1989). Data collected on multiple days for the same individual do not represent independent events but can be used to assess the amount of intra-individual variation. Additionally, estimates of consumption rates based on multiple days are preferable to estimates based on too few days (Anderson, 1988). Alternatively, data from one-day surveys can be used to estimate population averages if the sample size is large (Anderson, 1986).

Data obtained from single days are subject to potential biases from the effects of the day of the week or the season. Consumption data obtained on consecutive days may also be biased due to autocorrelation of food items consumed on adjacent days. The timing of the study period may or may not account for seasonal differences. The length of the study period also appears to have a large effect on the percent of the population determined to be consumers of fish and shellfish. Hu (1985) noted that the percent of the total population reporting consumption of fish was

greater in studies in which the length of the study period was longer and vice versa. For example, Hu observed that in a USDA three-day survey, 8.5% of the individuals reported using tuna, whereas in a one-week USDA survey, 27% of households used tuna and in the National Purchase Diary one-month survey, 67.8% of households used tuna.

Long-term recall surveys, on the other hand, may suffer from recall bias. Food diaries where individuals are asked to record daily food consumption can cover different time periods ranging from several days during a particular season to more than a year. Consideration must be given to participants' willingness and ability to follow directions in accurately recording numbers, types, and quantity of fish and/or shellfish consumed.

E. Regional considerations

Fish consumption and/or purchasing studies conducted across the U.S. have shown regional variation including differences for coastal areas compared with inland areas, seasonal differences in available species, and regional preferences for certain types of fish and/or shellfish (Javitz, 1980; Miller and Nash, 1971; Rupp et al., 1980).

Ebert et al. (1994) proposed that regional or local differences in climate, fishing regulations, accessibility to good fisheries, and availability of desirable target species may contribute to the variability in reported fish consumption rates. The productivity of specific water bodies may also have a bearing on survey results. Depending on the time period or season covered by different surveys, these factors may affect consumption rates of sport-caught fish. Thus, when comparing the results of studies conducted in different locations, in which the methodologies, time frames, or other parameters are not comparable, it is likely to be difficult to interpret apparent differences in consumption.

F. Data analysis and statistical considerations

Researchers reporting fish consumption rates may differ in their approaches to data analysis and the presentation of results. Data gathered from the same study may be analyzed by different researchers thereby yielding different results. The methods used to analyze data are not always consistent, and frequently, data tapes and analytical procedures, including data-cleaning decisions, have been lost, preventing researchers from checking and comparing analyses. Different ways of treating missing data or nonresponse bias can occur. Data may be stratified^b differently and stratification can affect the results, particularly for subgroups. Adjustments of the data such as log transformations or the application of weighting factors may also be inconsistent across studies and may result in different interpretations. Small sample sizes or low response rates may result in less reliable estimates, especially for subsets of the population. When sample size is small and the variance is large, the ability to compare groups is limited. If data are

^b Stratification involves defining subgroups within a population, such as by age, race, or geographic location, and then making random selections from each subgroup or stratum.

derived from household surveys rather than from individual data, calculations of consumption rates can not be made for age groups or by gender and should not be used to estimate percentiles of fish consumption (Javitz, 1980). Biases in data sets can be random across individuals or days, associated with a subset of the population, or systematic across the entire population (Anderson, 1986).

Fish intakes may be reported as distributions or as point estimates, usually a mean. However, when information about the distribution of values obtained is available, values derived for either end of the distribution may be based on only a few individuals. Fewer studies provide information on the median value as compared to the mean (average) value. When the variable of interest is normally distributed in a population, the mean and median values will be close (approximately equivalent). When a distribution is skewed (*e.g.*, lognormal), the mean and median can be substantially different. The mean represents the average value for the sampled population and in a skewed distribution, it will either be a higher or lower value than the median value and reflect a consumption rate for a different percentile of the population distribution than the 50th percentile. The median value represents the 50th percentile (or midpoint) of the distribution where half of the sampled population consume more, and half consume less, than the median value.

Measures of central tendency such as the mean and the median are used to represent a sample of observations more concisely than the full dataset. However, no single value will adequately represent a distribution which is highly skewed. The mean and median values each represent different points within the distribution, neither of which provides sufficient information to describe the full dataset unless some information about the shape of the distribution (such as the range or standard deviation) is also provided.

As an example, in a hypothetical population in which 75% of the people did not eat fish, even if the 25% that were consumers ate very large quantities, the median would be zero and, thus, would indicate that based on the *number* of consumers, the population on average did not eat any fish. In this case, the mean value would not represent actual average consumption for most of the people because most are nonconsumers.

On the other hand, in the above hypothetical example, using the median value to estimate risks from exposure to contaminants in fish would ignore the real consumption by consumers and result in a determination of zero risk. This conclusion would not protect 25% of the population. In this case, the mean would provide more information about the actual average *amount* of fish consumed, and would be more useful and more protective than the median value would be.

Although the hypothetical example chosen to illustrate the difference between the median and mean values may be extreme, it demonstrates the difficulty in characterizing the “average” in a population with a skewed distribution. This example indicates that for populations in which the variable of interest (consumption rate) is not normally distributed, neither the mean nor the median represent actual average consumption rates, and neither value in itself is adequate to

describe central tendency. In these cases, more information about the distribution is needed than a single value can provide.

Most populations display considerable variability in fish and shellfish consumption rates, and lognormal distributions of fish and shellfish consumption rates have been described for several populations (Ruffle et al., 1994; Murray and Burmaster, 1994; Hill and Lee, 1995). Thus, no single point estimate can describe the entire population, or the “average.” To adequately represent the population as a whole, it is preferable to perform a distributional analysis that will reflect the range and the distribution of consumption rates in the population.

The median will always represent the midpoint in the distribution, and for distributions based on consumption of fish and shellfish, the mean will typically represent a higher percentile than the median. Consumers with the highest levels of intake are represented in the upper tail of the distribution, between the 90th and the 99.9th percentile. This range represents plausible estimates of individual exposures at the upper end of the exposure distribution (U.S. EPA, 1995a). Upper level intake rates of fish and shellfish can be represented by any one of the upper percentile values, such as the 90th or 95th percentile. Some studies report one or the other, and thus it is difficult to select one of these values to represent “high-end” intake in all cases. U.S. EPA (1995a) considered the 99.9th percentile to be the bounding estimate for a population and stated that this value is expected to be greater than any actual exposure by an individual and thus can be used as a maximum upper bound or worst-case estimate which should encompass the entire population. However, estimates of extreme percentiles, including the maximum intake rate, can be unstable and highly uncertain when only limited data are available. As a result, for some distributions, the 95th or 99th percentile may provide a reasonable maximum or upper bound estimate of intake (Finley et al., 1994).

For risk assessment purposes, it is important to characterize a population as a whole in order to evaluate risks to individuals within that population. A distributional analysis will provide a description of the population and the variability within it. If a probabilistic determination of exposure is not done, reference points in the population distribution can be represented by use of several values from the distribution, such as the median (50th percentile), mean, and an upper level (90th or 95th) percentile or the bounding estimate (95th, 99th, or 99.9th percentile).

G. Summary of the potential sources of bias

Food intake surveys rely on food recalls, food diaries, or food frequency questionnaires obtained through the mail, telephone, or personal interview. Response rates, literacy, and language barriers may affect the quality of data collected in surveys. Other sources of bias in a survey include coding errors, interviewer bias, differential effort by interviewers or respondents, cultural differences in interpretation, recall bias or memory problems, and over- or under-reporting. Reporting errors may be inadvertent or intentional, and can relate to attitudes or perceptions held by the respondent. The wording and sequencing of questions can also affect the responses. As mentioned previously, sampling bias can result when the sample design is nonrandom and does

not accurately represent the target population. Additionally, correlations among subgroups can exist and become exaggerated when repeated samples (such as the collection of data on consecutive days) or clustered^c samples are used (Anderson, 1986). Assumptions about unknown factors, such as the number of consumers in a household or the amount of fish obtained and eaten, that are used to calculate rates of consumption may not be accurate and may not be consistent among studies. Finally, whether or not statistical tests have been performed on the data, one must evaluate the biological meaning and relevance of the results. An understanding of the overall survey design and data analyses procedures is essential when reviewing studies reporting fish consumption rates.

The following section of this report provides an overview of consumption rates that have been presented in the literature and a listing of the studies and analyses conducted, categorized by their applicability to identified populations and circumstances (*e.g.*, general population, consumers, fishers, geographic region). An evaluation of the strengths and weaknesses of key studies is included.

IV. REVIEW OF STUDIES USED TO DERIVE FISH AND/OR SHELLFISH CONSUMPTION RATES

A. Per Capita Estimates for Fishery Products - Disappearance into Commercial Marketing System

The Economic Research Service of the U.S. Department of Agriculture (USDA) annually calculates the amount of food available for human consumption in the United States and provides time-series data on food and nutrient availability (Putnam and Allshouse, 1994). The availability of food represents disappearance of food into the marketing system. Per capita estimates of consumption are derived by dividing total food disappearance by the U.S. population.

1. National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) within the United States Department of Commerce (USDC) annually prepares a publication entitled *Fisheries of the United States*. This publication contains information pertaining to commercially caught or processed seafood (fish and shellfish) entering commercial markets. Consumption rates in the annual publications are expressed as per capita rates for the civilian resident population, in pounds of edible weight for fresh, frozen, canned, and cured fishery commodities, and are presented for every year beginning with 1909. Although rates have shown some fluctuations, including a peak in 1987, the values presented by NMFS show an overall increase in consumption of fishery products over time. Table 1 presents commercial marine fish and shellfish per capita consumption rates for selected years between 1970 and 1993 as presented in the NMFS (1994) publication.

^c Clustering involves defining subgroups within a population, such as by household or ethnicity, selecting subgroups randomly, and then making observations or collecting data only within the subgroups.

To derive the per capita rates, NMFS (1994) conducted balance sheet calculations based on a “disappearance model.” Quantities of commercial seafood available for consumption were derived by deducting exports, inventory changes, and nonfood use from data on production, imports and beginning inventories for fresh, frozen, canned, and cured commercial fishery products. Civilian population size was estimated at the middle of the census period. Calculated per capita rates were based on an “edible weight basis.” No adjustments were made for spoilage or waste or for nonconsumers. The per capita rates derived by NMFS do not include sport-caught freshwater and saltwater fish, nor commercial fish or shellfish sold from “roadside” stands. NMFS (1987) reported that in addition to the consumption of commercially caught fish and shellfish, “recreational fishermen caught and consumed an estimated 3 to 4 pounds of edible meat per person.”^d As shown in Table 1, per capita consumption estimates increased from 11.8 pounds per year in 1970 to 15.0 pounds per year in 1993. These annual estimates correspond to 14.7 g/day and 18.7 g/day, respectively.

2. United States Department of Agriculture

USDA utilized the data gathered by NMFS to present similar per capita fish and shellfish consumption rates, based on disappearance estimates, in their publication *Food Consumption, Prices and Expenditures, 1970-93* (Putnam and Allshouse, 1994). Data maintained by the USDA for this series publication serve to document trends in food and nutrient availability for the United States. The yearly per capita food consumption values provided in USDA’s publication were derived by dividing total food disappearance by the total U.S. population on July 1 of the noted year. USDA estimated that per capita consumption of fish increased 3.2 pounds from 1970 to 1993 representing a 27% increase in average seafood consumption. Fresh and frozen fish and shellfish accounted for most of the growth. USDA also stated that “the lack of reliable estimates of game fish supplies means that fish consumption is likely understated” (Putnam and Allshouse, 1994).

3. Summary of Per Capita Consumption Rates Based on Market Disappearance Data

The results of studies of the disappearance of food products into commercial markets are used to evaluate trends in food and nutrient availability. Although food disappearance has been used as a proxy to estimate human consumption, and NMFS has used the data to calculate per capita consumption rates of fishery products, these rates have limited use for estimating consumption of fish and shellfish for several reasons. Disappearance data do not represent direct measures or provide accurate estimates of per capita consumption in the U.S. These studies do not account for what happens to the food when it “disappears.” As with any per capita estimate, no differences in distribution are considered. Although edible portions are estimated and used in the

^d No explanation for the derivation of this value was given. However, NMFS initiated a series of surveys in 1979 to estimate the amounts of participation, catch, and effort by recreational fishers in marine waters of the U.S. (NMFS, 1992). Although estimates of fish consumption were not reported, data from these surveys may have been used to estimate the amount of (marine) fish obtained from recreational fishing.

calculations, there are no measures of how much is eaten and how much of the food is wasted or spoiled. Assumptions about the relationship between disappearance and consumption are based on the premise that potential changes in food production and marketing practices over time do not alter the relative difference between food disappearance and food actually consumed. Most importantly, the data do not include noncommercial (sport-caught) fish or shellfish or any commercial fish or shellfish sold outside of commercial markets. However, the data can be used to evaluate whether the U.S. population consumes more or less of certain foods over time. Generally, the data have shown an increase in the availability (and disappearance) of commercial fishery products and thus it is assumed that consumption of fish and shellfish in the U.S. has increased over time.

B. Per Capita Consumption Estimates from National Consumption Surveys

Per capita consumption estimates for the overall U.S. population have been derived from national food consumption surveys conducted by the USDA and by national surveys specifically targeting fish and shellfish consumption. Rates for combined fish and shellfish consumption have been derived from these surveys. Rates differentiated by age, sex, race, and region, as well as rates differentiated by fish and shellfish have also been defined in some studies (discussed in further detail in the Discussion section). Different time periods and survey methodologies are reflected in the different studies. The per capita estimates average consumption for both consumers and nonconsumers of fish and shellfish and thus tend to underrepresent consumption rates for consumers. Noncommercial (sport) fish or shellfish cannot be distinguished in the national consumption surveys.

Various researchers have utilized the databases from national surveys and presented estimates of fish and shellfish consumption rates. In some cases, multiple analyses have been conducted on data derived from the same survey. However, the data tapes that each of the researchers received may not have been identical and the analyses that were performed were not exactly the same. These differences could account for the variation in results reported for the same study.

1. 1969-70 Market Facts Consumer Panel Survey

The National Marine Fisheries Service contracted with Market Facts, Inc. to conduct a consumer panel survey from February 1969 through January 1970 to determine consumption of major species of fish and shellfish at home and away from home, mainly for marketing purposes. A stratified sample of households was selected from a national panel designed to parallel U.S. census data. Pacific households (from California, Oregon, and Washington) represented 13.1% of the total sampled population. Heads of approximately 1500 households were asked to use a diary to record purchases twice per month of the types of fish and shellfish meals eaten at home and away from home for the entire household. No individual consumption data were collected; individual consumption values were derived by dividing total household consumption (as represented by purchases) by the number of household members.

Javitz (1980) stated that the results of the Market Facts survey were useful for estimating mean consumption, although it was unclear whether the survey included game fish. Javitz also claimed that unsophisticated methods may have been used to account for meals eaten away from home, and that the household-based data could not be used to derive percentiles or consumption rates by age or sex.

Finch (1973) used the data from the Market Facts Survey to develop a Model for the Estimation of the Consumption of Contaminants from Aquatic Foods (MECCA). The MECCA project estimated levels of mercury in 52 kinds of fish and shellfish and computed a frequency distribution of human ingestion of mercury from the fish and shellfish. Finch reported the mean per capita intake of fish and shellfish for the U.S. to be 14 g/day (Table 2). Values for the 99th percentile and the 99.9th percentile of fish and shellfish consumption were reported as 77 g/day and 165 g/day, respectively. The estimates of fish and shellfish consumption were based on records selected from families that reported for at least six months of the survey. The amounts of fish and shellfish reported as purchased in the Market Facts survey diary entries were converted to estimates of edible portions based on data on the yield of edible portions from purchased forms and from recipes. For restaurant meals, data on the amounts of fish and shellfish served by major institutional caterers were used to estimate portion size.

Hu (1985) included the findings of the Market Facts survey in his report comparing several seafood consumption studies. His analyses of the Market Facts data were based on the seafood consumption information reported by Nash (1971) and Miller and Nash (1971) because the data tapes Hu received were incomplete for certain types of fish and shellfish and could not be reconstructed. Hu claimed that the Market Facts dataset did not include “at-home” and “away-from-home” consumption information. Hu reported (based on data obtained from Nash, 1971) that the overall average annual per capita consumption of seafood at home was 13.5 pounds, which corresponds to 16.8 g/day (Table 2).

Nash (1971) reported annual per capita consumption in pounds, based on the Market Facts survey data, by a number of demographic variables including race, religion, income, geographic region, age, occupation, and education (of the head of household). Annual per capita consumption of total fish and shellfish was highest for Blacks (23.0 lbs/yr) and Jews (27.3 lbs/yr). Per capita consumption decreased as level of education increased, being highest among families in which the head of household had less than four years of high school. However, the relationship between income and per capita consumption was not linear and did not follow a consistent pattern.

Miller and Nash (1971) used the data provided by the Market Facts survey to evaluate consumption patterns of shellfish by demographic variables. They documented regional preferences for individual shellfish items as well as seasonal differences related to availability, and reported positive associations between high-income households and consumption of all types of shellfish except oysters. Pacific coast households showed the highest consumption rate of crabs, compared to other regions, and also ranked among the highest consuming regions for

clams and oysters. Out of nine regional rankings for total at-home consumption of fish and shellfish, the Pacific region ranked fifth, preceded by the Mid-Atlantic, South-Atlantic, West-South-Central, and East-North-Central regions.

2. 1973-74 National Purchase Diary (NPD) Survey

Under contract to the Tuna Research Institute, the National Purchase Diary Research, Inc. (NPD) conducted a fish and shellfish consumption survey from September 1973 through August 1974. The firm used a syndicated national purchase diary panel representative of the U.S. population (weighted sample) and additional families selected from specific subgroups. The overall sample frame consisted of approximately 9,600 households (approximately 7,000 households from the national panel, plus 2,400 households with a female head >35 years, and 200 Black families). The survey achieved an 80% response rate. The survey was administered to 1/12 of the total sample during each of twelve months of the survey (*i.e.*, respondents reported on fish and shellfish consumption for one month). Each participating household recorded the date of fish and shellfish purchase, the type of fish, whether fresh fish was recreationally caught or commercially purchased, the amount prepared per meal, the quantity consumed by each family member and guest (as opposed to per household), the amount of fish not consumed during the meal, and fish and shellfish meals eaten away and at home. Information was obtained on approximately 135 fish and shellfish items. Consumption information for 25,165 individuals from 7,662 households was gathered. Actual fish and shellfish consumption was reported for 24,652 individuals; this sample was estimated to represent, on a weighted basis, 94% of all U.S. residents (Javitz, 1980). Survey respondents were weighted on the basis of age, income, household size (but not less than two), census region, and market size.

Although the survey was planned to obtain comprehensive information about seafood consumption, there was incomplete documentation for the NPD data set (Javitz, 1980). Additionally, various researchers made assumptions in their respective data analyses which likely led to different derived per capita consumption rates. For example, population weighting factors, representational weights for mixed dishes containing fish or shellfish, and whether fish and shellfish consumed away from home were included were likely to contribute to variability in rates derived from the NPD data set. Although questions regarding consumption of game fish were included in the questionnaire, the distinction between sport-caught and purchased fish and shellfish was not maintained in the original compilation of data (U.S. EPA, 1989a), and consumption rates for commercial and noncommercial fish and shellfish could not be differentiated. Presumably, derived rates were inclusive of both commercial and noncommercial fish. However, in its Exposure Factors Handbook, U.S. EPA (1989a) stated that the per capita values derived from the NPD survey underestimated actual consumption rates for recreational fishers.

Cordle et al. (1978) analyzed the NPD data set and reported a consumption rate of 18.7 g/day for the average U.S. resident (Table 2). The U.S. EPA cited this value in the March 15, 1979 Federal Register in their "Water Quality Criteria Request for Comments." However, errors in the

database were later discovered that invalidated consumption values derived by Cordle and colleagues (Javitz, 1980).

Javitz (1980) conducted an in-depth analysis of the NPD data set for the U.S. EPA, after errors in the data set were identified and corrected. The corrected data tape contained consumption and demographic data for consumers only; this sample was estimated to represent 94% of the U.S. population. The overall average rate of fish consumption reported by Javitz was 14.3 g/day (Table 2).

Hu (1985) also carried out an analysis of the NPD data set. The data tape he received apparently did not contain information about away-from-home consumption. Hu reported that the overall average amount of seafood consumed was 12.3 pounds per year (corresponding to 15.3 g/day) which he identified as “at-home” consumption (Table 2).

Rupp et al. (1980) used the NPD survey dataset to derive percentile distributions of consumption for three age groups (1-11 years, 12-18 years, and 19-98 years), and by nine census (geographic) regions for freshwater finfish, saltwater finfish (no differentiation for estuarine was made), and shellfish. In general, their analyses showed that consumption increased with age. Per capita fish consumption was reported in kilograms per year for each region and for the entire U.S. population. They reported the average per capita consumption rate for freshwater finfish as 0.43 kg/year, saltwater finfish as 3.20 kg/yr, and shellfish as 1.01 kg/yr for the U.S. (Table 3a). These annual amounts correspond to 1.2 g/day, 8.8 g/day, and 2.8 g/day for freshwater, saltwater, and shellfish species, respectively. However, the number of people actually consuming freshwater fish, saltwater fish, and shellfish differed substantially (as discussed below). Regional differences in annual per capita consumption were also summarized. Mean per capita consumption by people living in coastal regions exceeded the national average for shellfish and marine finfish whereas residents of central (primarily inland) regions consumed more than the national average of freshwater fish (Table 3b). Coastal regions also showed a trend toward greater total consumption of fish and shellfish (derived by summing each category or type of fish) compared to inland regions.

Ruffle et al. (1994) developed a lognormal distribution based on the results of the NPD survey as reported by Rupp et al. (1980). Ruffle and colleagues indicated that the “results cannot necessarily be used to model the consumption of fish by sport or subsistence anglers from specific sites or from single water bodies.” The authors reviewed information provided by USDA and the USDC and concluded that consumption values had shifted upward by about 25% (between 16 and 27 percent) since the NPD survey was conducted in 1973-74. They recommended that adjustments be made to account for this increase in fish consumption, but also indicated that the data derived from the survey should still be useful in carrying out distributional risk analyses for the general population. Ruffle et al. (1994) presented distributions of fish and shellfish consumption rates and reported mean daily consumption rates of 10.68 g/day for saltwater finfish, 1.48 g/day for freshwater finfish, and 3.59 g/day for shellfish on a national per capita basis (Table 3c). Although these values are slightly higher than the rates presented by

Rupp et al. (1980), they do not include an upward adjustment for trends in increased consumption over time. The mean per capita values reported by Ruffle et al. (1994) for the Pacific region were slightly higher than the overall U.S. rates for saltwater finfish and shellfish (11.37 g/day and 4.05 g/day, respectively), and slightly lower for freshwater finfish (1.07 g/day; Table 3c).

3. 1981 Market Research Corporation of America (MRCA) Survey

The National Marine Fisheries Services contracted with the Market Research Corporation of America (MRCA) to collect 48 weeks of weekly purchase data and 14 months of monthly household fish and shellfish consumption data from December 1980 through January 1982. MRCA utilized their national consumer panel consisting of 7,500 households and 12,000 individuals. More than 500 detailed seafood items were included in the survey, and Hu (1985) called it “the most comprehensive seafood consumption survey ever pursued.” However, Hu reported that errors were found in both data processing and reporting, and that despite substantial efforts to correct them, unreliable rates of consumption (Table 2) resulted from conversion errors as well as from definitional problems and the high level of detail required for record keeping and reporting. Nevertheless, Hu indicated that the relative ranking of seafood products and the distribution of users by sociodemographic categories were similar to the patterns found in the other surveys he reviewed. One exception, reported by Hu, was a reversal in later studies, including the 1981 MRCA and the 1977-78 Nationwide Food Consumption Survey, of the inverse relationship between level of education and consumption of fish found by Nash (1971) in the Market Facts survey. Hu also used the data from the MRCA survey to compare at-home versus away-from-home consumption and concluded that at-home consumption constituted about 70% for fish and about 50% for shellfish of the total amount of fish and shellfish consumed.

4. USDA 1977-78 and 1987-88 Nationwide Food Consumption Surveys (NFCS)

The Consumer Nutrition Division of USDA has been conducting surveys on general food intake to describe food consumption behavior and to assess the nutritional content of diets. Information obtained through these surveys supports policy decisions related to food production and marketing, food safety, food assistance, and nutrition education (IBNMRR, 1992). The NFCS date back to 1936 and have been carried out every 10 years. The NFCS generally have targeted households in the 48 conterminous states and individuals residing in the households. The surveys have used a multistage stratified area probability sample^e taking into account geographic location, degree of urbanization, and socioeconomic considerations. Information on food intake over a three-day period was gathered. Individuals within each sampled household were asked to

^e Each successive sampling stage selected increasingly smaller and more specific locations. The 48 states were grouped into nine census geographic divisions; then all land areas within the divisions were stratified into three urbanization classifications - central city, suburban, and nonmetropolitan. The final number of total strata corresponded to the geographic distribution, urbanization, and density of the population within the conterminous United States as defined by the Bureau of the Census.

recall the kinds and amounts of foods eaten at home and away during the previous day and to keep a record of the foods eaten on the day of the interview and the following day (1-day recall and 2-day record). Overall, data reports for both surveys (1977-78 and 1987-88) provided information on food intake in grams per day from 64 food groups and subgroups. Mean per capita rates were derived for fish and shellfish combined, but these values did not include fish and shellfish in mixed dishes. The surveys conducted by USDA measured consumption of fish and shellfish in mixed dishes but reported the amounts for mixtures inclusive of all types of meat. Therefore, the amount of fish and shellfish consumed in mixtures could not be differentiated.

The 1977-78 NFCS obtained dietary intake records from 36,142 individuals (about 90% response rate) in 14,930 households (USDA, 1983). USDA derived an overall mean per capita rate of 12 g/day from the survey results (Table 2). At-home consumption represented about two-thirds of the average rate, or 9 g/day. Differences in food intakes calculated from one-day as opposed to three-day records were evaluated in 1977. The results showed a 9% difference in the reported average fish intake, 11 g/day compared to 12 g/day based on data from one and three days, respectively.

Hu (1985) conducted an analysis of the 1977-78 NFCS data, including fish and shellfish in mixed dishes, and derived a mean rate of 17.9 g/day for at-home consumption. Popkin et al. (1989) also included fish and shellfish in mixed dishes in their analysis of this survey, and derived a mean per capita rate for women aged 19-50 years of 18.3 g/day, as discussed below.

USDA (1993a) derived an overall mean per capita rate of 11 g/day from the 1987-88 NFCS. However, the 1987-88 NFCS only achieved a 31% response rate for individuals. The General Accounting Office (GAO, 1991) issued a report citing poor survey methodology and quality control problems which “raise doubts about the integrity of the data” and, therefore, limit the usefulness of the 1987-88 survey findings.

5. USDA 1985-86 and 1989-91 Continuing Survey of Food Intake by Individuals (CSFII)

For time periods in-between the nationwide food consumption surveys, USDA has been conducting the Continuing Survey of Food Intakes by Individuals (CSFII). These surveys serve to provide “timely information on U.S. diets and diets of population groups of concern and indicate changes in diets from previous surveys” (IBNMRR, 1992). The surveys utilize a multistage stratified area probability sample. Some changes in methodology were made for the 1985-86 CSFII compared to the 1977-78 NFCS (USDA, 1985). For example, participants were notified of the 1977-78 survey in advance and were asked to prepare notes on the foods used in the household in the week prior to the interview. These notes were expected to improve recall abilities. However, participants in the 1985-86 study were not contacted in advance of the survey. The later survey included additional questions and interviewers received additional training to probe for more detailed information. Also, participants in the later survey were asked

about their racial identity whereas racial designations were previously based on observations by the interviewer of whether the household respondent was Black, White, or other.

The 1985-86 CSFII specifically targeted women 19-50 years of age and their children aged 1-5 years in the 48 conterminous states. Although the CSFII studies may include additional population groups each year, this “core monitoring group” of women and children was selected because previous surveys showed that women of reproductive age and young children were more likely than other population groups to have diets low in certain nutrients (USDA, 1985). The 1985-86 survey included the collection of up to six one-day recalls at about two-month intervals during a one-year period from both a basic sample and a low income sample (at or below 130% of the poverty guideline). Response rates ranged from 57% to 75%. Not all participants provided six separate days of dietary data. As shown in Table 4a, mean per capita rates for women aged 19-50 years were found to be 11, 12, or 13 g/day, varying by year and/or the number of days of data. The percentage of the surveyed population reporting consumption of fish and shellfish ranged from approximately 10% from one-day data to 33% from four-day (nonconsecutive) data (USDA, 1985, 1987a, 1987b, 1988b).

Mean per capita consumption rates for low-income women were 9 or 11 g/day, also varying by year and/or the number of days of data. The percentage of women reporting consumption of fish and shellfish among the low-income group ranged from 7.5% from one-day data to 26% from four-day (nonconsecutive) data (USDA, 1986a, 1987c, 1988a, 1989).

Information on men aged 19-50 years was gathered in 1985 based on one-day dietary recalls obtained through personal interviews. The mean per capita rate reported for men was 21 g/day (Table 4a), representing a 50% increase from the mean rate of 14 g/day reported for men aged 19-50 years in the 1977 NFCS (USDA, 1986b).

Popkin et al. (1989) compared food group consumption trends between the 1977-78 NFCS and the 1985-86 CSFII for women aged 19-50 years and identified personal and household characteristics associated with food group trends. They found that changes in consumption behavior pertaining to various aspects of dietary intake were associated with demographic and socioeconomic variables, particularly the level of education of the female head of household. By using an average of three days of dietary intake of fish, shellfish, and mixed fish dishes from each survey^f, a mean per capita rate of 20.4 g/day was defined from the 1985-86 CSFII (Table 4a), compared with 18.3 g/day from the 1977-78 NFCS for women aged 19-50 years. The data from the 1985-86 CSFII were collected on three nonconsecutive days whereas the data from 1977-78 NFCS were collected on three consecutive days.

^f Although data were available for six days for some of the respondents in the 1985-86 CSFII, for comparative purposes, Popkin et al. (1989) used the 24-h food-recall data and two randomly selected days from the CSFII to obtain a sample comparable in number of days to the 1977-78 NFCS data.

The 1989-91 CSFII also included a general sample population and a low-income sample from individuals in households in the 48 conterminous states. The survey included the collection of three days of intake data (1-day recall and 2-day record). Only provisional data tables are currently available for the 1989-91 CSFII (USDA, 1994). Response rates for individuals with at least one-day intake records ranged from 54% to 66%. USDA derived mean per capita rates for men and women (≥ 20 years) of 17 g/day and 14 g/day, respectively, and an overall mean per capita rate of 13 g/day, based on one-day data (Table 4b). U.S. EPA is also conducting an analysis of the 1989-91 CSFII, inclusive of fish and shellfish from mixed dishes. Unpublished results from this analysis included an estimated mean per capita rate of 15.65 g/person/day (U.S. EPA, personal communication, Helen Jacobs, 6/97; Table 4b). These results were projected from a sample of 11,912 individuals to the U.S. population of 242,707,000 based on three-day data and using three-year combined survey weights.

Currently, USDA is conducting the 1994-1996 CSFII. For each survey year, a nationally representative sample of individuals has been asked to provide, through in-person interviews, food intake on two nonconsecutive days. USDA anticipates 15,000-16,000 respondents over the three-year period. Major differences in the current CSFII compared to previous ones are sampling to cover all 50 states, oversampling of low income populations, larger samples in selected age-sex categories (especially young children and the elderly), and subsampling within households rather than collection of information from all household members (USDA, 1993b).

6. 1992 National Health Interview Survey

The National Health Interview Survey (NHIS) was conducted in 1992 using a multistage stratified random sample representative of the noninstitutionalized population of the United States aged 18 years and older (Block, 1994). A food frequency questionnaire was used to gather information from respondents who reported their frequency of consumption of food items over approximately the prior year. Records of fish intake were limited to two categories, "fried" or "not fried" and information on shellfish intake presumably was not collected. A published report has not yet been issued from this study. Additionally, because the results were based on one-year recall and fish items were defined extremely broadly, the potential use of these data to evaluate fish and shellfish consumption is likely to be limited.

7. Summary of Per Capita Consumption Rates

The national consumption surveys varied in their purposes, methodology, and time frames. The NPD survey and the USDA surveys recorded consumption by individuals as opposed to purchases for household individuals in the Market Facts Consumer Panel Survey. The MRCA and NPD did not use random probability sampling methods and estimates for small subgroups tended to have large variance and, therefore, may not be reliable (Anderson, 1988). USDA studies relied on short-term recall and diary records (1-6 days) whereas most of the other surveys used monthly diaries. Some of the analyses of per capita consumption rates included fish and shellfish in mixed dishes, while others did not. Additionally, some of the estimates included only

seafood meals consumed at home. Given these differences, overall per capita consumption values for fish and shellfish combined ranged from 12 to 17.9 g/day, excluding rates that were reported to be unreliable (Table 2). These results are based principally on national studies that were conducted in the 1960's, 1970's, and 1980's (with only preliminary information available from more recent studies) and the estimates have not been adjusted for upward trends in seafood consumption rates. Only limited information is available from the national surveys to differentiate consumption rates between fish and shellfish (see Discussion on shellfish). Data from the national surveys were not usually differentiated for commercial and sport fish and shellfish, and typically can be used only to derive total consumption for both of these categories combined or for commercial species alone. Trends in fish and shellfish consumption related to demographic variables will be discussed in more detail in the Discussion section.

The analyses performed by Rupp et al. (1980) on the NPD dataset provided information about annual consumption of freshwater fish, saltwater fish, and shellfish including regional summaries of the percentage of users. Data from the NPD survey were used by U.S. EPA to derive water quality criteria (Stephan, 1980) and consequently appear to have had far-reaching effects^g. However, the fish consumption rates that were derived from this per capita study may not represent current per capita rates for fish and shellfish consumption. Although the NPD survey and several of the other national surveys provided fairly consistent results, the data were obtained many years ago and may be outdated. Ruffle et al. (1994) pointed out that the amount of fish and shellfish consumed in the U.S. increased roughly 25% since the time of the NPD survey and that the results should be viewed in light of trends over time. Comparisons of surveys from different time periods (*e.g.*, Hu, 1985) have also shown changes in the relationships between consumption of fish and shellfish and various demographic factors. For these reasons, more recent surveys (such as the 1989-91 CSFII and subsequent ones) are needed to provide more current information concerning the general population of the U.S.

However, even more current estimates of per capita fish and shellfish consumption have limited applicability. As stated outright by Nash (1971) and reiterated by Hu (1985), point estimates of fish and shellfish consumption rates derived from national per capita studies are subject to both spatial and temporal errors and thus are not projectable to the U.S. population. As one example, the differences in the reported percentage of users based upon the number of days that data were collected in the USDA studies reflect the inadequacy of short-term surveys (covering a few days) for detecting all people who consume fish and/or shellfish since fish and shellfish are not typically consumed on a daily basis. The other significant limitation with national per capita studies, such as those conducted by USDA, is that they do not address sport fish and shellfish. It is thus not possible to ascertain to what extent, if any, the per capita estimates of consumption derived from these data include consumption of sport fish and shellfish.

^g The validity of using per capita estimates of fish consumption for determining water quality criteria is questionable, especially when only a small portion of the U.S. population was reported to consume freshwater species presumably obtained from water bodies affected by the criteria.

Per capita consumption rates generally are useful as a measure of trends or changes in demand for the entire population. A comparison of per capita rates from sequentially conducted national studies usually indicates whether, on average, the entire population is consuming more or less of a specific food group. Changes in per capita rates do not indicate specifically whether more or fewer people are eating the food or whether those eating it are eating more or less. In summary, per capita rates are not truly representative of consumption rates, particularly for populations in the U.S. that actually consume fish and/or shellfish.

C. Consumption Rates for Consumers Derived from National Surveys

Per capita rates average consumption for both consumers and nonconsumers of fish and shellfish and thus provide an underestimate for actual consumers. Therefore, “consumer only” consumption rates are preferable to per capita rates for use in describing actual consumption of fish and shellfish in the U.S. Combined fish and shellfish consumption rates for actual consumers or “consumers only” have been derived from several nationally based surveys, the 1973-74 NPD survey, the 1977-78 NFCS, and the 1985-86 CSFII. Analyses of the data from the 1989-91 CSFII are currently in progress. A review of rates derived for consumers only from these national studies is presented in the following section and in Table 5.

1. 1973-74 National Purchase Diary Survey

Rupp et al. (1980) suggested that differences in rates of consumption for consumers only compared to national per capita rates were greatest for freshwater fish and shellfish consumption. In their analysis of the NPD dataset, there was not much difference between per capita estimates and actual consumption of saltwater fish. These differences (or lack thereof) would be expected because most of the population reported consumption of saltwater fish, but fewer people ate freshwater and shellfish species. Rupp and colleagues reported that about 94% of children and 96-100% of adults in the U.S. ate some kind of fish and/or shellfish, and that about 90% of the total population reported consumption of saltwater finfish. However, only 26-42% of the population ate shellfish and only 12-16% ate freshwater finfish. Although Rupp et al. (1980) focused on per capita consumption in the U.S. and in specific geographic regions, they reported annual “per capita” estimates of consumption for consumers only as well as for the entire U.S. population^h. Annual per capita consumption of saltwater finfish by consumers only was 1.1 times that of national per capita consumption (3.52 kg/yr compared to 3.2 kg/yr). Annual per capita consumption of freshwater finfish by consumers was 5.7 times the estimate for the general population (2.43 kg/yr compared to 0.43 kg/yr), and annual per capita consumption of shellfish by consumers was 2.9 times the national per capita consumption (2.91 kg/yr compared to 1.01 kg/yr). The average “per capita” rates of consumption for “consumers only” for freshwater,

^h Note that “per capita” consumption rates typically refer to the national population and thus would include both consumers and nonconsumers. However, Rupp et al. (1980) also provided annual “per capita” estimates for consumers only as well as for the entire U.S. population.

saltwater, and shellfish species correspond to 6.7 g/day, 9.6 g/day, and 8.0 g/day, respectively, for consumers of all ages; average rates for adult consumers were slightly higher (Table 3a).

Rupp et al. (1980) reported that the percentage of the population consuming each type of fish or shellfish varied on a regional basis (Table 3b). Among adults, the percent of people consuming saltwater species ranged from 31% (in the West-North-Central region) to 93% (in New England). The percent of adults consuming freshwater fish ranged from 5% (New England) to 25% (West-South-Central), and shellfish consumers ranged from 30% (East-North-Central) to 60% (New England).

2. USDA 1977-78 Nationwide Food Consumption Survey and 1985-86 CSFII

Using data from the 1977-78 Nationwide Food Consumption Survey, Pao et al. (1982) derived frequency distributions for rates of consumption of different foods by actual consumers, *i.e.*, individuals who reported consuming specific food items at least once during the three-day (consecutive) study period. Pao et al. reported average quantities of fish and shellfish consumed per day and per meal (at specified percentiles) for ten age groups and by sex for six of the age groups. They also reported the percentage of users. Out of 37,874 individuals with three-day diet records, 24.5% reported eating fish and shellfish at least once in the three days; 20.5% reported eating fish and shellfish consumption for only one of three days, 3.6% for two out of three days, and 0.4% reported eating fish and shellfish on all three days. These results indicate that only a small percentage of people are likely to eat fish and/or shellfish as frequently as every day. However, these summary statistics which were based on data obtained from only three days can not be used to determine actual frequencies of consumption.

Pao et al. (1982) reported an overall mean rate for fish and shellfish combined of 48 g/day (Table 5) for “consumers only” compared to the per capita rate of 12 g/day. Fish and shellfish mixtures were not included in the analysis. The average consumption rate for finfish was slightly higher at 54 g/day. Finfish did not include canned, dried, or raw fish. (This rate can not be compared to per capita consumption of finfish because USDA reports only provided values for fish and shellfish consumption combined.) Pao et al. (1982) also indicated which food items and food groups were most frequently reported to be consumed by survey participants. The most frequently reported finfish included fishsticks, flounder, haddock, and perch. Canned tuna and shrimp were reported as frequently consumed seafood items.

Popkin et al. (1989) included fish and shellfish in mixed dishes in their analysis of consumption behavior for women aged 19-50 who reported consuming fish and shellfish in the 1977-78 NFCS and 1985-86 CSFII. They derived a mean intake of 111.0 g/day compared to a per capita rate of 18.3 g/day which they determined from the 1977-78 NFCS, and 88.2 g/day compared to their per capita estimate of 20.4 g/day from the 1985-86 CSFII (Table 5). Their analysis also showed a higher percentage of consumers in the 1985-86 CSFII (44.7%) compared to the 1977-78 NFCS (36.7%).

In comparison, Pao et al. (1982) derived mean rates of 44 g/day and 49 g/day for women consumers only, aged 19-34 and 35-64 years, respectively, from the 1977-78 NFCS. However, Pao et al. (1982) did not include fish and shellfish in mixed dishes in their report. Whether this difference in methodology accounts for most of the disparity in results is difficult to ascertain. Estimates of consumption that include fish and shellfish consumed in mixed dishes are likely to be more realistic than estimates which do not include this source, although the reliability of the results depends on how accurately the portions of fish and/or shellfish consumed in mixed dishes are estimated.

3. USDA 1989-91 CSFII

As indicated previously, USDA has released only provisional data tables which provide limited information on the results of the 1989-91 CSFII and do not give rates of fish and shellfish intake for consumers. U.S. EPA's analysis of the 1989-91 CSFII dataset which is currently in progress includes fish and shellfish consumed in mixed dishes and uses a data base that provides actual proportions of fish, shellfish, and other ingredients in mixed dishes (*e.g.*, breadings on fishsticks). Therefore, the results are expected to be more accurate than estimates based on assumptions about the proportions of ingredients (*e.g.*, the assumption that 50% of a mixed dish is fish and/or shellfish) (U.S. EPA, personal communication, Helen Jacobs, 2/96). As yet unpublished results estimated a mean rate of 100.63 g/person/day for consumers of fish and shellfish, including fish and shellfish consumed in mixed dishes, from a sample size of 3,927 projected to a population size of 89,800,000 using three-year combined survey weights (U.S. EPA, personal communication, Helen Jacobs, 6/97; Table 5). An estimated rate of 253.38 g/person/day was determined for the 95th percentile. "Consumers" were defined as individuals who consumed fish at least once during the three-day reporting period; if a respondent consumed fish and/or shellfish more than one time during the three-day period, their daily average was calculated.

4. Summary of Consumption Rates for Consumers Only

Only a few national surveys have provided estimates of fish and shellfish consumption rates for "consumers only." Rupp et al. (1980) provided annual values of per capita consumption of freshwater fish, saltwater fish, and shellfish for consumers as well as for the overall U.S. population, but did not report consumption rates for total fish and shellfish consumed. Pao et al. (1982) reported a mean rate for "consumers only" of 48 g/day based on their analysis of the 1977-78 NFCS data. The analyses performed by Pao and colleagues did not include fish and shellfish in mixed dishes and, therefore, is likely to underrepresent actual consumption rates for consumers. Popkin et al. (1989) derived mean rates for women consumers only, aged 19-50 years, inclusive of fish and shellfish in mixed dishes, of 111.0 g/day from the 1977-78 NFCS survey and 88.2 g/day from the 1985-86 CSFII. Although it is difficult to compare their results with those reported by Pao et al. because the target populations evaluated were not equivalent (in age), the consumption rates reported by Popkin et al. suggest that fish and shellfish consumed in mixed dishes contribute significantly to the overall consumption rate for consumers. Preliminary

results from the 1989-91 CSFII substantiate this assumption as the estimated mean rate for consumers of all fish and shellfish including mixed dishes was 100.6 g/day.

The USDA data are more current than the NPD data but were based on short-term dietary recall records whereas the NPD data were collected from one-month sampling periods. U.S. EPA (1989) indicated that data from the USDA studies using one to three-day records for “consumers only” are more appropriate for assessing acute exposures than chronic exposures. Only respondents that consumed fish or shellfish during the three-day reporting period were included in the calculated rates. In addition, because the USDA surveys did not ask respondents about frequency of consumption, the data can not be used to estimate “typical” long-term consumption rates for actual consumers. Thus, the national studies do not adequately address consumption by consumers; a different study design (including frequency of consumption) is needed to more accurately determine consumption rates for consumers.

The estimates provided by Pao et al. (1982) are the only currently published reports of consumption for consumers in the U.S. based on a national survey. The analyses currently in progress by U.S.EPA on the more recent 1989-91 CSFII which will include mixed dishes will provide information that is more current and more accurate with respect to the inclusion of fish and shellfish in mixed dishes. However, as noted, the results from the national surveys for “consumers only” provide an incomplete estimate of consumption of fish and shellfish by consumers because the data are obtained only from respondents that ate fish or shellfish in the three-day reporting period, and frequency of consumption was not determined. Therefore, the results do not characterize long-term consumption rates and may not accurately estimate “typical” consumption for consumers.

In summary, the available data from national surveys for “consumers only” are limited. Therefore, it is difficult to determine an overall average rate for consumers in the U.S. because none of the analyses adequately characterizes average rates of consumption over time for consumers of fish and shellfish in the overall U.S. population. Additionally, results from national studies typically have failed to adequately address consumption of sport fish and shellfish. A review of studies pertaining to consumption rates and patterns for people who catch and consume their own fish and shellfish is presented below.

D. Consumption Rates Reported for Consumers of Sport (Noncommercial) Fish and Shellfish

Consumption values for populations who consume sport fish and/or shellfish can range widely from those who fish intermittently to those who fish regularly for recreation or sport, or to those who fish mainly to provide a dietary staple (subsistence fishers). These fishing populations are poorly represented in the national studies discussed previously which did not distinguish between consumption of commercially harvested and noncommercial or sport-caught fish and/or

shellfishⁱ. U.S. EPA (1994, 1995a) suggested that recreational and subsistence fishers represent subgroups that are likely to consume higher average rates of fish and shellfish than those reflected in national consumption surveys of the general population.

Various regional studies have been done to define consumption rates relevant to people who consume sport fish and/or shellfish. Some of these studies have looked at total consumption (sport and commercial) and others have looked only at fish caught and consumed from specific water bodies during certain seasons. Studies which have derived consumption rates for sport fish are summarized below. The methodologies used in these studies of fishing populations differ from the methods used in the national studies, and include mail surveys, creel surveys, and personal interviews with fishers and/or consumers of noncommercial sport fish and shellfish.

1. Combined Commercial and Sport Fish Consumption Studies

a. 1988 Michigan Statewide Survey

From January to June 1988, West et al. (1989a) conducted a mail survey of a sample of 2,600 Michigan sport fish license holders, stratified by license type and geographic residence. Fish consumption information was gathered from all members of the household for a seven-day recall period. Fish meals included self-caught, market, restaurant, and gift fish. Respondents estimated fish meal size by using a picture of “about 1/2 pound” and were asked to judge whether each fish meal was “about the same, less, or more” than the pictured fish meal. Meal size was recorded as 8 oz., 5 oz., or 10 oz., accordingly.

West et al. (1992) applied statistical tests to the results of the survey to compare rates of consumption among different subpopulations and to test for the interaction of demographic factors such as race, income, age, level of education, and residence (including size of town). Their main objective was to identify subgroups, especially minorities, with especially high rates of consumption who would thus be potentially at greater risk of exposure to chemical contaminants. They surveyed all members of households that consumed fish in order to assess potential risks to family members as well as anglers, and then adjusted for the lack of independence among household members by reducing the acceptable error rate. (An alpha level of $p = 0.05$ was considered marginally nonsignificant.) They noted that the sampled population may not have represented subsistence fishers because it was selected from licensed anglers only.

West et al. (1992) reported an overall mean rate for fish consumption of 18.3 g/person/day (GPD) for the winter-spring period for sport fishermen and their family members who ate fish. West and colleagues indicated that data from the summer-fall months would be expected to yield higher rates of consumption due to an expected increase in fishing effort during these seasons. Because the overall response rate was only 47.3%, the authors adjusted the population mean

ⁱ As defined by U.S. EPA (1995a), populations who consume noncommercial (sport-caught) fish are people who catch and consume their catch and the people with whom they share their catch.

value downward by 2.2 g to account for nonresponse bias, thus deriving a mean rate of 16.1 GPD (Table 6). Derivation of the adjustment factor was based on a followup telephone survey of respondents and nonrespondents and is explained fully in West et al. (1989b). Nonresponse bias was not measured for subgroups. Therefore, the mean rates of consumption reported for subgroups were unadjusted, as were the variance calculations (such as the rate reported for the 80th percentile). For comparative purposes, the unadjusted overall mean rate is presented in Table 7.

West et al. (1992) examined the effects of age, race, income, education, and residence on consumption. Differences by age were found to be statistically significant, with older anglers (over 65 years) having the highest average fish consumption rate (25.2 GPD). West et al. (1992) found that minority subgroups combined (Black, Native American, and Other) had higher mean rates of consumption compared to Whites (21.7 compared to 17.9 GPD), but the difference was “marginally nonsignificant.” Most other trends related to demographic variables (as described below) were also marginally nonsignificant or nonsignificant, although the highest consuming subgroups (*e.g.*, low income Native Americans) had consumption rates nearly twice the overall average. Although the results did not show statistical significance, they may indicate patterns and trends in consumption, as described below.

Native Americans and Blacks had the highest mean rates of consumption, 24.3 and 20.3 GPD, respectively (Table 7). Patterns among these two highest consuming groups differed considerably. Middle-income (\$15,000-\$29,000) Black anglers had higher consumption rates than lower and higher income Black anglers. Native American anglers with either low or high income had higher mean rates of consumption than middle-income Native Americans. Older (51-91 years) Black anglers and low income (<\$15,000/year) Native Americans were the highest consuming subgroups, 31.9 and 33.7 GPD, respectively. White anglers demonstrated little difference by income level, and for the surveyed population as a whole, the relationship between consumption and income was nonsignificant. The relationship between consumption and level of education was marginally nonsignificant.

West et al. (1992) found a significant, but nonlinear, relationship between fish consumption and place of residence (degree of urbanization). Consumption (mean intake) was highest by Native Americans living in rural areas and small towns (32.1 and 29.9 GPD, respectively) and among Blacks, the highest mean rate was for those living in cities (23.9 GPD). The number of years of residence in Michigan also had a significant positive (linear) relationship with fish consumption; the highest mean rate (30.3 GPD) was for Black anglers who had lived in the state more than thirty years.

Murray and Burmaster (1994) used the data from the 1988 Michigan Statewide Survey to derive distributions of fish consumption rates for survey respondents. They defined categories (not mutually exclusive) of consumers as those who ate fish, those who ate self-caught fish, and those who ate Great Lakes fish. For each category, they evaluated rates of consumption of both sport fish and total fish for all adults, men, women, and anglers, and presented empirical (Table 8) and

parametric distributions for 12 of these population subgroups. The data analyses performed by Murray and Burmaster differed from those conducted by West and colleagues in several ways. Murray and Burmaster used the raw data without applying weighting factors to data obtained for different time periods and analyzed consumption data for all adults, whereas West and colleagues evaluated consumers only and included all ages. However, the estimated mean consumption rates calculated by West et al. for “consumers only” included a relatively large percentage (56.6%) of anglers and household members who had not eaten any fish during the seven-day recall period. In contrast, the distribution of consumption rates reported by Murray and Burmaster applied only to those (adult) respondents who had eaten fish during the recall period. Murray and Burmaster (1994) demonstrated that the distributions for fish consumers were lognormally shaped and proposed that the distributions could be used in Monte Carlo simulations.

Murray and Burmaster calculated a mean intake of 45.3 g/day for total fish consumption for all adult respondents that ate fish (Table 8). For anglers who reported eating self-caught fish, the mean intake rates were 45.0 g/day for sport fish, and 55.1 g/day for total fish (from all sources). In general, the mean intake rates for anglers were slightly higher than the mean intake rates for other consumers in the same category, suggesting that the angler eats only slightly more than (adult) family members and other adults who share the catch. Anglers who reported eating Great Lakes fish had the highest mean intake of fish from all sources, 61.3 g/day, which included an average of 20.4 g/day of fish from other sources in addition to 40.9 g/day of Great Lakes fish. Murray and Burmaster (1994) reported that the category of anglers reporting consumption of Great Lakes fish consisted of 89 people or four percent of all adult respondents, and 2.6 percent of all respondents.

Anglers who ate Great Lakes fish also had the highest median intake (53.1 g/day) and the highest intake rate at the 95th percentile (123.9 g/day) for total fish consumed. The median rates for the other population subgroups ranged from 32.7 to 40.8 g/day, including both sport fish and total fish consumption (Table 8).

b. 1991-92 Michigan Sport Anglers Fish Consumption Study

With additional funding from the Michigan Great Lakes Protection Fund, West et al. (1993) conducted a year-long study in order to more thoroughly evaluate fish consumption rates in Michigan. Previous funding had only allowed for a six-month study to be conducted which did not include the seasons considered to be important fishing seasons (summer and fall). The objectives of the 1991-92 study were similar to the previous survey: to test assumptions about fish consumption rates used to establish water quality criteria, to determine angler compliance with consumption advisories, and to determine which subpopulations might be at greatest risk of exposure to chemical contaminants as a result of consuming fish at higher than average rates.

A random sample of 7,000 licensed anglers, stratified for geographic residence and type of license, was selected to receive a mail survey covering fish consumption over a seven-day period.

Twenty-five cohorts were staggered throughout the year to capture a full year cycle of consumption behavior. As in the previous study, the data were weighted to equalize the frequency of responses in each two-week period. In contrast to the earlier study, the sampling unit was the license holder only rather than all household members that consumed fish. The rationale for this change was that statistical interdependence of consumption by household members could be avoided, and additionally, the previous study had already addressed the question of whether family members consumed equivalent amounts of fish. (They were found to consume proportionately less corresponding to body weight.) The survey found that about 93% of licensed fishers ate fish (and 94% of those that did not eat fish had eaten fish in the past). All anglers who indicated that they were fish consumers were included in the estimates of consumption rates although approximately 70% of them had not eaten fish during the recall period. Because the mail survey return rate was 46.8%, and funding did not allow for followup calls to nonrespondents, West et al. (1993) used the same downward adjustment of 2.2 g (applied to the overall average rate of consumption) that was determined and applied in the earlier 1988 study. Data analysis in the final report delineated consumption for sport fish only as well as for total fish (Table 6), and also provided frequency distributions for sport fish and total fish. Sport fish included any fish from Michigan waters including the Great Lakes and Michigan rivers that flow into the Great Lakes. Total fish included both sport fish and commercial (restaurant and market) fish. The authors noted that a “sizable (but unknown) amount of commercial fish come from Michigan surface waters.”

Sport fish consumption averaged 14.5 GPD and total fish consumption averaged 24.3 GPD (both rates adjusted for nonresponse bias). West et al. (1993) tested whether mean fish consumption rates differed in the winter-spring period compared to the summer-fall period in the 1991-92 study and found no significant differences. Therefore, seasonality did not appear to affect consumption rates. The difference in rates derived from the two studies may have resulted from differences in methodology, including a larger sample size (nearly three times) in the later study.

West et al. (1993) also evaluated the relationship between education, income, residence, race or ethnicity and sport fish and total fish consumption, respectively. They demonstrated statistically significant relationships between sport fish consumption and income. In the bivariate analyses, the two lowest income groups (<\$14,999/year and \$15,000-24,999) had the highest mean rates of sport fish consumption (21.0 and 20.6 GPD, respectively). For total fish consumption, however, consumption rates did not vary with income level. Minority anglers had significantly higher mean rates of consumption than White anglers for both sport fish (23.2 compared to 16.3 GPD) and total fish (35.9 compared to 25.9 GPD) consumption. Racial and ethnic variables were not broken down into individual minority subgroups due to low sub-sample sizes, but the two main groups included in the “minority” category were Black anglers and nonreservation Native American anglers. In contrast to the earlier 1988 study, no significant relationship between age and consumption was evident. Males ate significantly more sport fish than females. However, gender differences were nonsignificant for total fish consumption. The relationships between education and fish consumption were not significant, although the patterns differed for sport fish and total fish consumption. For example, anglers with post-graduate education tended to

consume less sport fish but more total fish relative to anglers with less education. Mean consumption rates differed significantly for sport fish only by place of residence (size of town); the highest mean rate (22.8 GPD) was for small towns (population size 100-2,000). In the multivariate analyses, the authors documented a significant combined and interactive effect between race/ethnicity, income, and fish consumption such that lower income minorities ($\leq \$24,999$) had the highest mean sport fish consumption level of 43.1 GPD and the highest mean total fish consumption of 57.9 GPD.

In the earlier study, West and colleagues evaluated the stability of fish consumption data over time by comparing the results reported by a subset of the sample population who responded to both the initial mail survey and a followup telephone survey conducted one year after the initial study. West et al. (1989c) suggested that a decline in fish consumption between 1988 and 1989 may have reflected a “suppression effect” due to consumption advisories and/or increased awareness of potential risks as a result of participation in the survey. In the later study, West et al. did not find a significant suppression effect, although they reported that 46.8% of anglers who were aware of advisories had decreased the amount of fish they consumed. They also documented some changes in methods of preparation or cooking and choice of location or species, particularly for anglers fishing in the Great Lakes (compared to those fishing rivers, inland lakes, and river mouth lakes).

c. 1988 New York Statewide Angler Survey

Under contract with the New York State Department of Environmental Conservation, Connelly et al. (1990) conducted a statewide mail survey to estimate the amount of effort and expenditure by fishers on certain waterways and for certain species, and to identify fishing patterns, preferences, and attitudes of anglers during 1988. Surveys were sent to 17,000 fishing license holders and a response rate of 62.4% was obtained. Two questionnaires were used, with one of the questionnaires being sent to roughly half of the selected sample. Consumption of fish was addressed by only one of the questionnaires which included one question regarding all fish meals (sport-caught or purchased fresh, canned, or frozen) consumed by the responding angler in 1988 and one question regarding the number of meals of sport-caught fish from Lakes Erie and Ontario consumed by the angler’s household in 1988. The number of respondents reporting on consumption was 1,190 (7%) and only limited results concerning consumption were included in the final report. An overall average fish consumption rate for statewide anglers of 45.2 meals/year was reported. Connelly et al. (1990) assumed a half-pound portion of fish per meal to derive a mean consumption rate of 10.1 kg/year or 28.1 g/day. Sport fish consumption was reported for Lake Ontario only (an average of 6.9 meals/year). The authors stated that consumption appeared to increase with increasing age, income, and education. Although the study included a comprehensive survey of many waterways used for fishing throughout the state, estimating fish consumption rates was not a stated objective of the study, and the information provided on consumption, particularly for sport fish, was limited.

d. 1985 Wisconsin Angler Study

The Wisconsin Division of Health conducted a cross-sectional study of licensed Wisconsin anglers to assess sport fishing and fish consumption habits and to evaluate comprehension and compliance with the state's fish consumption advisory (Fiore et al., 1989). Questionnaires were mailed to 1600 licensed anglers, containing questions regarding fish consumption in 1984, targeted species, kilograms caught and kept for eating by family members, fish preparation, cooking methods, demographic characteristics, and knowledge of and compliance with the Wisconsin fish consumption advisory. The study also measured body burden of PCBs and DDE (in 200 respondents) to determine possible correlations between sport-caught fish and body burden of PCBs and DDE. Fifty percent of anglers returned survey questionnaires.

The mean number of sport-caught fish meals reported for 1984 was 18 and the mean number of commercial fish meals was 24. The mean number of all fish meals reported was 41. For anglers only who reported eating fish in 1984, the mean number of fish meals was 42. Although the survey was not specifically designed to obtain respondents' daily fish consumption, the authors derived an estimated daily fish intake from both sport-caught and commercial sources by assuming an average meal size of 227 g (8 oz.). They estimated a mean daily intake of 26.1 g/day, and 63.4 g/day at the 95th percentile, from all fish meal sources (sport-caught and commercial). The mean daily sport-caught fish intake was estimated at 12.3 g/day, and at the 95th percentile, 37.3 g/day (Table 6).

e. 1994 Urban Fishers and Crabbers in New York/New Jersey Harbor Estuary

May and Burger (1996) reported on fishing and consumption behavior and risk perception by fishers and crabbers using one of three regions along the New Jersey shore where fish and shellfish consumption advisories had been issued. Interviews were conducted with a total of 318 fishers or crabbers from the three regions, including 46 crabbers, 221 fishers on shore and 100 fishers on party boats, from May through September 1994. Data on location, activity, weather, residence, age, and occupation were recorded and the interviews included questions on the frequency of fishing, catching and eating fish, cooking methods, and awareness and understanding of advisories. Estimates of the average serving size and frequency of consumption were calculated for each region as well as average and "worst case" rates of consumption in the most heavily fished region, Arthur Kill. All fishers and crabbers at a location were approached for interviews and most agreed to participate (although only one person per group of fishers was interviewed and individuals were not interviewed more than one time). May and Burger (1996) reported on the percentages of people eating their catch and percentages purchasing commercial species. However, their estimates of consumption did not distinguish between commercial and sport-caught fish and shellfish.

Most fishers and crabbers were male, and age varied among regions, ranging from 36 to 48 years old on average. Most fishers (85%) and crabbers (91%) at Arthur Kill were local residents whereas the percentages of residents fishing in the other two regions were considerably lower

(27% and 25%). At least 70 percent of fishers in all regions indicated that they consume their catch. The overall average number of times fish were eaten was 4.6 times per month. The average serving size ranged among regions from 10.3 to 11.5 ounces. Over forty percent of the fishers reported that more than half of the fish consumed was self-caught, and twenty percent ate only self-caught fish. Most fishers (78%) also indicated that they buy commercial fish, and 58 percent indicated that more than half of the fish they eat are purchased in the store. Most fishers said they did not fish during winter, however, some reported freezing their catch for consumption at other times of the year. May and Burger (1996) also noted that sixty percent of those interviewed at Arthur Kill, and 28 percent and 30 percent of fishers in the other two regions, had heard warnings about consuming fish from the area.

In the Arthur Kill region, more than 75 percent of crabbers ate their catch and more than 65 percent indicated that at least three-fourths of the crabs they ate were self-caught. Forty-six percent reported eating only self-caught species. An average of 9.5 crabs were eaten per meal at an average frequency of 3.7 times per month; the maximum frequency was sixteen times per month. Most crabbers reported cleaning the crabs to remove the hepatopancreas; fewer than three percent said they ate whole crabs.

May and Burger (1996) multiplied the average (4.8) and maximum (20) number of fish meals eaten per month by average serving size to calculate estimates of average and “worst case” consumption rates for fishers in the Arthur Kill. They determined average and worst case consumption rates for fish of 52.8 g/day and 220 g/day, respectively. These rates included both sport-caught and commercial fish. They similarly determined average and worst case consumption rates for crabs, using 160 grams of muscle per crab, of 187 g/day and 810 g/day, respectively.

2. Fish Consumption Rates for Sport Fish from Marine and/or Estuarine Water Bodies

a. 1991-1992 Santa Monica Bay Seafood Consumption Study

The Santa Monica Bay Restoration Project contracted with the Southern California Coastal Water Research Project and MBC Applied Environmental Sciences (SCCWRP and MBC, 1994) to conduct a seafood consumption study from September 1991 to August 1992. The objectives of the study were to describe the demographic characteristics of “recreational anglers^j” fishing in Santa Monica Bay, California, to assess their seafood consumption patterns, to identify ethnic subgroups of the population with high consumption rates, and to determine species being caught and consumed at the highest rates. The survey form included a census and a questionnaire. The census served to collect information about site characteristics such as location and weather

^j The fishers interviewed in this study were referred to as “recreational anglers” although they included people fishing for shellfish and thus were not necessarily limited to anglers using the hook-and-line method to obtain their catch.

conditions, and to record the number of anglers at specific survey sites and some basic demographic characteristics (*e.g.*, ethnicity, gender, and age) of the observed fishing population. The questionnaire was administered to randomly selected anglers fishing from piers and jetties, private boats, party boats, beaches, and rocky intertidal zones. It consisted of a series of questions personally administered by interviewers to individual anglers to obtain information on site characteristics and the angler's fishing history, consumption patterns, age, gender, ethnic background, and household income.

During the summer months (September 1991 and June through August 1992) interviews were conducted during two weekday/weekend sets (a set consisted of one weekday plus one weekend day) per month for each of the three major fishing modes^k, for a total of 12 surveys per month. During nonsummer months (October 1991 through May 1992) interviews took place on one weekday and one weekend day per month for each of the three fishing modes for a total of six surveys per month. Fishing modes, geographical regions, and specific sites were selected prior to the study to maximize spatial coverage. Sampling times and sequence were randomly selected each month. Late-night fishers who fished only during the night would have been excluded from the sample population.

Twenty-nine sites were surveyed on 99 days of sampling for a total of 113 surveys, with 2,376 anglers included in the census (41% on party boats, 37% on piers, 20% on private boats, 1% on beaches, and 0.5% at rocky intertidal sites). Over 1,200 (71%) interviews took place out of 1,740 attempted interviews (571 anglers in nonsummer months and 672 anglers in summer months). Of the successful interviews, 555 anglers (45%) provided information used to derive consumption rates. Interviewers encountered the lowest success rate (66%) on piers. Interviewees were asked whether they had been interviewed previously; the number of repeated interviews was seven. For those who completed interviews, 93% were male and 7% were female, with the majority (54%) between the ages of 21 and 40 years. The results of the census showed that about one-third of the respondents had not fished in the bay during the four weeks prior to the interview, and that a small population, 2% of the respondents, appeared to fish every day. Thus, this study targeted fishers exhibiting a broad range of fishing effort, and was likely to have included some subsistence fishers.

SCCWRP and MBC (1994) identified ethnic groups among those interviewed and reported the composition of the subpopulation used to derive consumption rates as being approximately 40% Whites, 10% Blacks, 25% Hispanics, 22% Asians (consisting of Filipinos, Japanese, Koreans, Chinese, and Vietnamese), and 3% Other (consisting of one Thai, one East Indian, three Samoans, three Hawaiians, three Indonesians, one Guamanian, and one Malaysian). Interviewers were able to administer the questionnaire in English, Spanish, Vietnamese, Chinese, and Tagalog. Of the successfully completed non-English speaking interviews, 95 were conducted in

^k Fishing mode refers to the type of place or platform from which fishing occurred. NMFS identified three fishing modes: 1) shore, including piers, jetties, breakwaters, bridges, beaches, etc., 2) party or charter boats, and 3) private or rental boats.

Spanish and four in Vietnamese. Language barriers (Korean, Armenian, and a few others) prevented interviews with 149 (9%) of the anglers that were approached (Allen et al., 1996). In comparison to the ethnic composition of Los Angeles County in 1990, SCCWRP and MBC indicated that the surveyed population of Santa Monica Bay anglers had a greater proportion of Asians, Whites, and other ethnic groups, a much lower proportion of Hispanics, and a similar proportion of Blacks.

Annual household income information was not available for 27% of responding anglers. Of those providing information on income, about one-third (32%) reported incomes greater than \$50,000, 39% reported incomes between \$25,000 and \$50,000, and 19% reported incomes between \$10,000 and \$25,000. About 6% reported incomes between \$5,000 and \$10,000, and 5% reported annual incomes less than \$5,000. The majority of Hispanic anglers reported annual household income in the lower income brackets (<\$25,000) whereas the majority of all other ethnic groups reported annual household incomes exceeding \$25,000, and the majority of Korean and Chinese anglers reported incomes greater than \$50,000.

A larger proportion of respondents who reported on consumption were encountered on boats (61%) than on land (39%). With respect to ethnicity and fishing mode, Hispanics fished most often on piers and jetties, and Whites were most represented on party and private boats. Asians (mainly Koreans and Chinese) ranked second for fishing on party boats. With respect to household income and fishing mode, respondents with annual incomes less than \$25,000 tended to fish on piers and jetties, while those with incomes greater than \$25,000 tended to fish from party boats and private boats.

Anglers were questioned about consumption of eight commonly consumed species of fish as well as about fish they had in hand. Consumption rates were calculated by multiplying the angler's estimate of his/her typical meal size of a species relative to a balsa wood fillet model representing 150 g (*e.g.*, twice as much, three times as much, half as much, etc.) by the frequency of consumption of that species in the four weeks (28 days) prior to the interview. For fishers with fish in hand, the frequency of consumption was increased by one to account for consumption of the catch present at the time of the interview. For fishers without fish in hand, photographs were used to identify species, and only those anglers that had eaten the species in the prior four weeks were included in the estimates of consumption rates.

A second method of calculating consumption rates based on fish in hand and estimates of the amounts available for consumption ("consumable portions") was also employed. However, because the "fillet model" method was based on specific information provided by the anglers and utilized fewer assumptions, it was considered more appropriate to use than the "consumable portions" method. A comparison of the results using each method showed no significant differences in median consumption rates for all species combined although the rates derived for individual species were more variable (Allen et al., 1996). Consumable-portion method estimates were generally higher than fillet-model estimates for larger-sized species and lower for smaller-sized species.

Analysis of the consumption data showed that the overall mean consumption rate for Santa Monica Bay anglers was 49.6 g/day, with those in the Other group (represented by 14 individuals mainly of Pacific Island origin) having the highest mean consumption rate (137.3 g/day) compared to the White, Hispanic, Black, and Asian groups (Table 9). SCCWRP and MBC (1994) reported using a one-way analysis of variance (ANOVA) to compare consumption rates by ethnicity and found significant differences. Pairwise comparisons showed that Whites had a significantly higher rate of consumption than Hispanics, and individuals in the Other group had a significantly higher consumption rate than Filipinos, Hispanics, Japanese, and Whites.

SCCWRP and MBC (1994) found the frequency distribution of consumption rates to be highly skewed (to the right) and recommended the use of medians and upper percentiles for describing central tendency and variation. (The mean rate of 49.6 g/day roughly corresponded to the 75th percentile of the frequency distribution for consumption by the respondents.) The median consumption rate for the overall surveyed population was 21.4 g/day. Median consumption rates for the various ethnic groups ranged from 16.1 to 85.7 g/day, with Hispanics having the lowest median rate, followed by Whites and Asians (both 21.4 g/day), Blacks (24.1 g/day), and those in the Other group having the highest median rate (Table 9). SCCWRP and MBC (1994) selected the 90th percentile to represent upper level consumption rates. Among ethnic groups, these values ranged from 64.3 to 173.6 g/day, again with Hispanics having the lowest and Other having the highest rates.

With respect to income, SCCWRP and MBC (1994) found that the lowest income group (<\$5,000/year, reported by 20 respondents) had the highest median consumption rate (32.1 g/day) of all income groups. However, the highest income group (>\$50,000/year, reported by 130 respondents) had the highest mean consumption rate (58.9 g/day) and the highest consumption at the 90th percentile (128.6 g/day). Mean and upper level (90th%) consumption rates increased as income increased, with the exception of the lowest income group (<\$5,000) which had mean and upper percentile rates in the mid-range. It should be noted that a larger percentage (two-thirds) of the population of consumers was comprised of higher income anglers (>\$25,000/yr).

SCCWRP and MBC (1994) also demonstrated that median consumption rates differed by fishing mode, with party boat anglers (21.4 g/day) consuming more than pier and jetty or private boat anglers (16.1 g/day). Hispanics, who predominated in the lower income brackets, accounted for almost 39% of the pier and jetty anglers. The ethnic groups having the greatest annual household income were most abundant on party and/or private boats, and included Whites, Koreans, and Chinese. These results suggest the possibility that those who could afford to fish from boats, had greater fishing success, and thus consumed more fish.

Consumption data for the Santa Monica Seafood Consumption Study have principally been presented by SCCWRP and MBC (1994) as consumption rates, *i.e.*, grams per day or kilograms per individual per month. Although information on meal size was obtained in the survey, data have not been presented to summarize information regarding usual or typical meal size or meal

frequency. With respect to preparation and cooking methods, about 65% of the anglers reported consuming steaks/fillets, 33% consumed fish whole/gutted, and 1% reported eating whole fish with intestines. Among the ethnic groups, Asians were more likely to eat fish whole/gutted than other ethnic groups. White anglers were more likely to eat fish steaks/fillets and least likely to consume fish whole/gutted. Frying was the most common cooking method for each ethnic group.

In a separate analysis of the data from the Santa Monica Bay Seafood Consumption Study, Hill and Lee (1995) demonstrated that the Santa Monica Bay consumption data could be well described by a lognormal distribution suitable for use in probabilistic simulations, and also presented empirical distributions for fish consumption among four ethnic subgroups. Hill and Lee (1995) combined individuals in SCCWRP and MBC's original Other group with the Asian subgroup to form a larger Asian subgroup (similar to what Puffer et al., 1982, described below, did to define their Oriental/Samoan group) with a mean consumption rate of 60 g/day (Table 9). Their analysis demonstrated that Asians, inclusive of Pacific Islanders, and Whites had significantly greater consumption rates than Hispanics.

In Hill and Lee's analysis, median rates of consumption ranged among ethnic groups from 16.1 g/day (Hispanics) to 24.1 g/day (Blacks). Greater variability existed at the upper percentiles. For instance at the 95th percentile, Blacks had the highest consumption (225 g/day), followed by Asians (192.9 g/day), Whites (160.7 g/day), and Hispanics (85.7 g/day) (Table 9). In contrast to SCCWRP and MBC (1994), Hill and Lee chose the 95th (rather than the 90th) percentile to represent upper level intake.

b. 1980 Los Angeles Metropolitan Area Survey

In an earlier (1980) survey of the Los Angeles metropolitan area represented by the Santa Monica Bay, Puffer et al. (1982) assessed consumption rates of potentially hazardous marine fish and shellfish by local nonprofessional (noncommercial) fishermen. A total of 1,059 fishers were interviewed at twelve sites, including people fishing from piers, shore, and breakwater areas, as well as party boats, but not private boats. No fisher was interviewed more than once during the year-long study period. Surveys were conducted approximately three times per month on different days and at different times. Surveyors recorded the number of fishers at a site, and their sex, race, and approximate age. Interviews were conducted only with successful fishers (those with fish in hand). Ethnic groups in the survey population included Caucasian (42%), Black (24%), Mexican-American (16%), and Oriental/Samoan (13%), but interviews were only carried out in English.

Daily consumption for each species caught was based on fish in hand and was calculated using an equation that factored in the number of fish or shellfish in the catch, the average weight in the catch, the edible portion by weight of the species, the number of fish eaters in the family/living group, and the frequency of fishing per year. It was assumed that the number of family fish eaters was constant over the study period and that the catch was shared equally among family

members. Additionally, assumptions about the number and average weight of the fish representing a typical catch for a given fisher were used to estimate consumption. The authors noted that the survey may have been biased toward the most frequent fishers and underrepresented youths (≤ 17 years) who fished with older family members.

Puffer et al. (1982) estimated the median amount of sport fish and/or shellfish consumed to be 36.9 g/day and the 90th percentile to be 224.8 g/day (Table 10). Significant differences in consumption rates were found by age and by ethnicity. Individuals over 65 years had the highest median rate of consumption (113.0 g/day). Among ethnic groups, Puffer et al. (1982) found that the Oriental/Samoan group had the highest median consumption rate (70.6 g/day), followed by Whites (46.0 g/day), Mexican-Americans (33.0 g/day), and Blacks (24.2 g/day). Consumption by fishing mode or by income was not reported. About half of the respondents reported eating fish one to two times per week, and about 20% reported eating fish greater than, or equal to, three times per week. The authors also found that 71% of the respondents reported freezing fish for later consumption.

Puffer et al. (1982) reported that shellfish, primarily crabs and mussels, comprised 3% of the catch, although they did not indicate whether this percentage was based on edible weight, amount consumed, or some other factor. They also reported that shellfish (including crabs, mussels, and abalone, collectively) were among the 12 primary types of “fish” kept by sportfishers, that three percent of the fishers interviewed obtained shellfish, and that 97 percent of them consumed the catch. They estimated the median rate of consumption of shellfish at 10.0 g/day/person.

c. 1988-89 San Diego Bay Health Risk Study

The San Diego County Department of Health Services (SDCDHS, 1990) conducted a study to estimate the potential health risks associated with consuming fish from San Diego Bay. Certified SCUBA instructors interviewed 369 anglers using a survey questionnaire at popular fishing locations (boat launch areas, piers, and shorelines) over a one-year period to identify fish species most commonly caught in the bay, to identify demographic characteristics of anglers, and to characterize fish consumption patterns. Consumption rates were derived assuming the catch was evenly distributed among consumers within a household and that 30% of the measured catch was edible. Fishing frequency was also factored into the equation. “Individual” rates (per interview) were calculated and used to derive a bay-wide consumption average that applied weighting factors for the number of consumers per “individual” consumption rate. (For example, a rate that applied to six consumers would count six times as heavily as one that applied to a single consumer.) Average rates based upon the subset of the population that caught and ate fish were then adjusted to account for the percentage of interviewed anglers who had not caught fish at the time of the interview. Only 59 anglers provided all the necessary data for calculating individual fish consumption rates in addition to indicating that they fish year-round.

The authors derived an overall bay-wide fishing population mean of 31.2 g/day. Five ethnic subpopulations were identified (White, Filipino, Hispanic, Asian, and Other). Although the

authors suggested that Filipinos and Asians consumed fish at higher rates than Whites and Hispanics, consumption rates for ethnic groups could not be reliably estimated because sample sizes were inadequate. Sample size for the overall survey of anglers was also small. Therefore, the results provide only limited information about consumption rates among San Diego Bay fishers.

d. 1993 San Francisco Bay Seafood Consumption and Information Project

The Save San Francisco Bay Association (SSFBA) released a report *Fishing for Food in San Francisco Bay: Part II*, that described a study they conducted from September to November 1996 to obtain information about demographic traits and fish consumption habits of people fishing from ten San Francisco Bay public piers (Wong, 1997). Surveyors conducted personal interviews with approximately 200 people fishing or crabbing, using a questionnaire and fish fillet model (representing 150 g) to assist with estimating the amount of fish eaten at a meal.

Ninety-one respondents (42%) reported having eaten fish from the bay in the prior 30 days. These respondents were then asked to recall for the prior seven days the amount of bay-caught fish consumed by himself/herself only. Sixty-two respondents (29%) reported consumption of bay-caught fish in the 7-day period preceeding the interview; the information provided by these people was used to estimate median consumption by ethnic group and overall. However, sample sizes for each ethnic category were small and the differences reported were not compared statistically. Overall, SSFBA calculated a median consumption rate of 32 g/day and reported that of those people that ate fish and/or shellfish from the bay, 90% exceeded health advisory recommendations (which were in effect during the survey). The ethnicities of the 62 respondents reporting consumption of fish or shellfish from the bay during the prior seven day period were African American (10%), Asian/Pacific Islander (60%), Caucasian (13%), Latino (11%), and Mixed Race (6%). Although this is the sole study of fish consumption behavior for fishers in San Francisco Bay, the selection of survey sites was nonrandom and sample sizes were small. Therefore, this study provided limited information on consumption rates and demographic characteristics for San Francisco Bay fishers. However, the study obtained supplemental information on fishing and consumption behavior including the consumption of organs and tissues other than muscle fillets.

e. 1980 Commencement Bay Seafood Consumption Study

Pierce et al. (1981) interviewed about 500 fishermen from July through November 1980 for the Tacoma-Pierce County Health Department in Washington to identify fish and shellfish consumption habits and demographic characteristics of noncommercial fishermen fishing in four subareas of Commencement Bay. The objectives of the survey were to determine the extent to which local species of fish and shellfish (specifically crustacea) were used as food and which species were most commonly consumed, to assess methods of preparation of the catch, and to develop a health risk model. Only successful fishermen were interviewed, and salmon caught by interviewed fishermen were not included in the study because they were considered to have

minimal contact with Commencement Bay pollutants due to their migratory behavior. Surveys were conducted in the mornings and evenings. Each subarea was sampled five times during the first half of the survey (summer) and four times during the second half (fall), except for one area that was sampled only twice during the second half. The boat fishing area was sampled four times during the second half of the survey only. Although sampling periods sometimes lasted as late as 1:00 a.m., the authors noted that a considerable portion of total catch was suspected to have been obtained during all-night fishing. The racial composition of the surveyed population was reported as White (60%), Black (23%), Oriental (15%), and Mexican (2%).

In the first half of the survey, which did not include boat fishing, the authors derived a mean daily catch of 208 pounds, and estimated that approximately 95% of the catch, representing 197 pounds of fish or seafood, would be taken home by fishermen for personal consumption. This amount corresponds to about 3.5 lb. of fish per fisherman, representing 1.7 pounds of edible tissue. The average size living group (household) for the surveyed population was determined to be approximately 3.5 persons. Thus, dividing 1.7 pounds by 3.5 persons results in nearly one half pound per person per day. The addition of boat fishing during the second half of the survey increased the average daily catch to 409 lb., representing about one pound of edible fish tissue per person per day.

U.S. EPA (1989a) used the estimated daily consumption rates derived from this study¹ of 23 g/day at the 50th percentile and 54 g/day at the 90th percentile, in combination with the consumption rates reported by Puffer et al. (1982), to derive recommended default values for recreational fishers (as discussed below). However, because salmon catch was excluded from the study, the actual consumption of fish and shellfish could have been considerably higher than what was calculated. On the other hand, the study did not address consumption rates for fishers who did not have fish or shellfish at the time of the interview. Additionally, sampling did not include the winter or spring periods. Therefore, the results of this study provide only a crude estimate of the amount of catch available for consumption by fishers in Commencement Bay.

f. 1983-1984 Puget Sound Survey

Landolt et al. (1985, 1987) conducted a two-year study of recreational anglers' fish and shellfish catch and consumption from four urban embayments of Puget Sound^m. The objectives of the study were to identify the most commonly consumed species, demographic characteristics of the fishing population, and patterns of consumption (including frequency, amount, and methods of preparation), and "to estimate the quantity of selected chemicals consumed by anglers and their families." Species-specific catch and consumption information was obtained through personal interviews. Over 4,000 shoreside anglers were interviewed the first year (November 1983

¹ It is not clear how the consumption rates reported by U.S. EPA were derived as they do not match the amounts of edible fish tissue reported by Pierce et al. (1981). The average amounts reported by Pierce et al. correspond to approximately 38 g/day excluding catch from boats, and 78 g/day including boat fishing.

^m The authors used the term "angler" although this survey included squid and crab in the catch.

through November 1984). Initially, sampling times were selected at random and interviews were conducted at all times of the day, until the most preferred fishing times were identified. Subsequent sampling focused on those times when the most fishers were expected. Apparently no effort was made to avoid repeated sampling. The second year of the study focused primarily on chemical analyses of tissue specimens caught during the first year, but catch and consumption patterns for boating anglers at two of the embayments were also evaluated. During the second year, 437 boating anglers were interviewed from February to October 1985.

Calculations of consumption rates were based on estimates of the weight of the catch (fish in hand) divided by the number of consumers reported for the household, and by the number of days since fish caught at the same site were last eaten. This value was multiplied by a cleaning factor of 0.3 for fish and 0.49 for squid and crab to derive the mean daily grams of available edible portion consumed per person. Geometric means were then calculated for each embayment and ethnic group. Consumption rates were reported as geometric means for all non-U.S. born Asians, and subpopulations of Filipino, Southeast Asian, and Chinese-Japanese, and for U.S. born groups including Whites, Blacks, and Asians (Table 10). Species-specific consumption was also characterized for the time period in which that species was present in the fishery.

Landolt et al. (1985, 1987) derived an overall geometric mean daily fish consumption rate of 11 g/day for all ethnic groups and species. Quantities consumed varied by site and by species, and ranged from 8 to 14 g/person/day (geometric means) among embayments. Consumption rates for the most common species were considerably higher than the overall average. For example, the most common species, squid, was consumed at a rate of 39 g/day (geometric mean). However, this rate was only applicable in the season (Fall) in which the species was obtained. Landolt et al. (1987) noted that boaters fished predominantly for salmon, and consumed 51.7 g/person/day (geometric mean) of King salmon from the two bays where boating anglers were surveyed.

Landolt et al. (1985, 1987) reported that the “average” shoreside fisher in Puget Sound was employed (57%), male (92%), educated for at least 12 years (77%), and White (69%). Preferred fishing times varied by embayment but peaked at all locations between 6:00 p.m. and midnight. More fishing occurred during the fall, when squid was sought. The “average” boating angler was reported to be employed (69%), male (96%), educated at least 12 years (91%), and White (86%).

The following ethnic differences were reported as significant findings. Ethnicity was correlated with fishing mode, with Blacks fishing more from bridges and Whites fishing more from boats. Asians had larger numbers of fish eaters per household than other ethnic groups, were more likely to fish on weekdays or at night, and were more successful at catching fish. Asians were more likely to consume portions of the catch other than the fillet. Asians and Whites were more likely to be employed than other ethnic groups. Whites were more likely to be interviewed repeatedly. Seasonality was an important factor for Blacks who fished more during the spring and less during the winter than Whites or Asians.

3. Fish Consumption Rates for Sport Fish from Freshwater Bodies

a. 1990 Consumption of Freshwater Fish by Maine Anglers

ChemRisk (1992) conducted a mail recall survey of licensed freshwater anglers in Maine in order to determine potential exposure to dioxins from certain water bodies. The population of interest was defined as all respondents who fished in either the 1989-1990 ice fishing or 1990 open water fishing seasons (actual time frames not provided) and all respondents who did not fish but consumed Maine sport fish from the identified sources. Questionnaires were mailed to 2500 resident anglers holding inland (freshwater) licences; 1612 anglers (64%) responded with usable data. Respondents reported the number of trips made or planned during the 1989-1990 ice fishing and 1990 open-water fishing seasons, the number of each of 15 species caught (14 species were identified and a line was provided for “other”), the number of fish consumed for each of the 15 groups of species, and the number of fish taken from flowing or standing water bodies. Anglers were also asked to estimate the average length of each species consumed. Estimates of the amounts consumed were calculated using equations that factored in species-specific length-mass relationships and edible percentages, number of household consumers, and time over which fish was consumed.

The authors reported that the mean rate of consumption for consumers of fish from all types of freshwater bodies (including lakes, ponds, rivers, and streams) was 6.5 g/day (Table 11), assuming that the catch was shared equally among a mean household size of 2.5 persons. They also reported a mean rate of 3.7 g/day for consumers of fish obtained only from rivers and streams.

Ebert et al. (1993) noted that the results were subject to recall and self-reporting biases, and that advisories were in place during the survey period. Additionally, about 80% of the respondents practiced “catch and release” even on undesignated (unrestricted) water bodies. A number of other factors were also likely to have contributed to the findings of relatively low rates of consumption. Fishing in Maine, particularly in freshwater bodies, would be limited due to seasonal climatic effects on water bodies and thus the availability or accessibility of fish. The actual length of time of legal fishing seasons was not defined in the report. The survey covered a limited target population. Members of the Native American Penobscot population were only sampled if they obtained a complimentary license to fish waters outside of their land. Therefore, most of the fishing effort by this subpopulation would not have been included in the survey. Finally, the authors suggested that the low rates of consumption of freshwater species in the state were not surprising given the greater availability of saltwater species (both recreationally and commercially).

U.S. EPA (1995a), in their review of this study, stated that “these results suggest that Maine fishers consume less than the entire fish and nonfish consuming population, an assumption that contradicts the empirical evidence of recreational fishing localities, commerce, and cookbooks that have arisen precisely around the fresh and saltwater recreational fishing industry in Maine.”

U.S. EPA referred to this study as an “outlier” and an example of why caution should be exercised when reviewing consumption studies and determining the applicability of the results.

b. 1991-92 Columbia River Basin Fish Consumption Survey

The Columbia River Inter-Tribal Fish Commission (CRITFC) entered into a Cooperative Agreement with U.S. EPA to conduct a fish consumption survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin (CRITFC, 1994). The objective of the survey was to identify individual tribal members’ consumption rates, patterns, habits, and preparation methods of anadromous and resident fish species caught from the Columbia River Basin. Concerns regarding exposure to dioxins and other waterborne toxics through ingestion of contaminated fish prompted the survey. Personal interviews conducted on the four tribal reservations resulted in achieving the targeted 500 interviews (69% response rate from 744 total individuals randomly selected from health records to achieve representation from four tribal lists). A total of 513 tribal members 18 years and older were surveyed over a three-week period in November 1991; respondents also provided information for 204 children aged five and younger. The survey questionnaire included a 24-hour diet recall and questions regarding seasonal and annual fish consumption (*e.g.*, average number of fish meals weekly). Foam sponge food models approximating 4, 8, and 12 oz. fish fillets were used to help respondents estimate the amounts of fish consumed.

Although tribal members were randomly selected to participate, respondents were subsequently self-selected in that they chose to appear at the interviews held in a centralized location on each reservation. People living farther from this center may not have been as well represented, and more females than males chose to participate in the study. The interviews took place in November which was one of the designated months of lower consumption. The authors also noted that consumption rates may have decreased relative to consumption by tribal members in the past as a result of diminished supplies (availability of fish) over time. The data on consumption were weighted to account for differences in population size among tribes in order to obtain an unbiased population mean from the pooled (four tribes) dataset.

CRITFC (1994) presented consumption rates that were derived by averaging consumption for both consumers and nonconsumers (*i.e.*, based on a population sample that included both fish consumers and nonfish consumers) in order to be more representative of the tribal population as a whole, although they indicated that this rate would not be appropriate for risk assessment. The mean rate of consumption for all surveyed adults (consumers and nonconsumers) throughout the year was determined to be 58.7 g/day. Seven percent of respondents indicated they did not consume fish. Excluding nonconsumers, the mean rate of fish consumption for consumers was 63.2 g/day (Table 12). Most fish were consumed during the months of April through July, resulting in a mean rate of 108 g/day during May and June, the two months most frequently indicated to be high fish consumption months. November through February represented months where fish were consumed the least. In January and December, the two most frequently chosen months of low fish consumption, survey respondents consumed, on average, 30.7 g/day. Overall,

the researchers reported the mean rate of consumption during the high months (April-July) as being three times higher than the mean rate of consumption in low months (November-February).

Approximately 83% of the 204 tribal children five years of age or younger were reported to eat fish. The mean rate of consumption for children who consumed fish was 19.6 g/day. The calculated mean consumption rate for nursing mothers or mothers who had nursed was 59.1 g/day, nearly the same amount of fish as the general tribal population. Female tribal members had a mean intake of approximately 56 g/day, significantly different from the mean of 63 g/day for males. Respondents reported consuming the fillet, skin, head, eggs, bones, and other organs. Baking and pan-frying were the most commonly reported cooking methods. Canning and smoking were also reported as common methods for preserving fish. The species most commonly consumed were salmon, lamprey, and smelt, of the anadromous species, and trout, of the resident species; salmon was consumed in the greatest quantity.

c. 1992 Sulphur Bank Mercury Mine/Clear Lake, CA - Biological Testing

Harnly et al. (1997) collected and analyzed blood, hair, and urine samples for mercury from 68 individuals living near an inactive mercury mine bordering Clear Lake, a large recreational lake. Interviewers personally administered a questionnaire covering fish consumption (sport fish caught from Clear Lake and commercial fish) over the six-month period prior to the interview, as well as potential inorganic mercury exposures to participants. Respondents included 63 members of the Elem Native American community bordering the old mine site and five additional nearby residents. For the 23 individuals reporting consumption of Clear Lake fish, the average amount consumed was 60 g/day (Table 12). The report also indicated that 32 individuals reported consuming commercial fish (canned tuna was the most common type) at an average rate of 24 g/day. The authors did not indicate what portion of the population ate both sport fish and commercial fish, and did not estimate consumption rates inclusive of both sport-caught and commercial fish. It should be noted that health advisories recommending limited consumption of fish from Clear Lake were in effect during the survey.

4. U.S. EPA Derived Consumption Rates for Recreational and Subsistence Fishers

As noted previously, data from the 1973-74 NPD were used by U.S. EPA to derive water quality criteria based upon a consumption rate of 6.5 g/day that was derived from analyses of the NPD dataset by Stephan (1980). Apparently as a result, a default value of 6.5 g/day for consumption of fish and shellfish has been applied in innumerable instances regardless of the appropriateness of this value and/or without an adequate understanding of its derivation and applicability. U.S. EPA has continued to use 6.5 g/day to represent a default consumption rate for the general (per capita) population (U.S. EPA, 1995b). In fact, despite the claim that the value represents the general U.S. population, including both consumers and nonconsumers, U.S. EPA proposed using

it to derive screening valuesⁿ for target analytes in fish in the context of providing guidelines for developing consumption advisories for consumers of sport fish (U.S. EPA, 1995b). However, the 6.5 g/day value was derived for per capita consumption of nonmarine (freshwater and estuarine) species only, and the percentage of users of nonmarine species was determined to be only about 14 percent of the U.S. population. Additionally, U.S. EPA claimed that the NPD survey did not adequately address consumption of fish and shellfish by recreational or noncommercial fishers. Furthermore, the 6.5 g/day value is markedly different from the other consumption rates that U.S. EPA has proposed for use in describing consumption by recreational and/or subsistence fishers, as described below. In the revised edition of the first volume of their guidance series *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*, U.S. EPA (1995b) noted that the 6.5 g/day consumption rate value is currently under review. Additionally, they recommended that States evaluate and use fish consumption rates that are appropriate for their region, and use local consumption rate data when available.

Other agencies have adopted the 6.5 g/day default value although, in many cases, there is little or no understanding of the origin or applicability of this value. As an example, West et al. (1993) reported that the State of Michigan used 6.5 g/day to represent fish consumption by the general population in the state although no studies had been conducted to determine whether this rate was appropriate for the general population in Michigan. West and colleagues further explained that when questioned about the origins of the value 6.5 g/day, the State of Michigan claimed that it was derived from Javitz (1980). West et al. (1980) pointed out that Javitz (1980) did not report an estimate of fish consumption at this rate (6.5 g/day) but reported a mean consumption rate from the NPD survey of 14.3 g/day and reported on several other national surveys which derived consumption rates similar to, or greater than, that derived from the NPD. Additionally, West and colleagues noted that the data from the NPD had been destroyed and that U.S. EPA had not been able to replicate the 6.5 g/day value. Thus, West et al. (1993) proposed that the 6.5 g/day value derived from “unlocated and unreplicable origins.” Hence, it seems evident that the widespread use of 6.5 g/day as a default value for fish consumption, particularly for sport fishers, has been unjustified and inappropriate.

In the Exposure Factors Handbook, U.S. EPA (1989a) reported that national per capita estimates of fish and shellfish consumption (*i.e.*, the rates derived by Javitz, 1980, from the 1973-74 NPD) underestimate actual consumption rates for recreational fishers, and recommended that values derived from two regional surveys of recreational fishers (*i.e.*, Puffer et al., 1982, and Pierce et al., 1981) be used to represent consumption rates for recreational fishers in any area where there is a large water body present and widespread contamination is evident. U.S. EPA (1989a) averaged the results reported in these two studies to derive recommended values of 30 g/day at

ⁿ U.S. EPA (1995b) defined screening values as “concentrations of target analytes in fish or shellfish tissue that are of potential public health concern and that are used as standards against which levels of contaminants in similar tissue collected from the ambient environment can be compared. Exceedance of these screening values should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted.”

the 50th percentile, and 140g/day at the 90th percentile (Table 13). U.S. EPA indicated that no specific values could be recommended for small water bodies due to the lack of data, and suggested that local studies of recreational fishers would need to be conducted in order to estimate consumption rates for specific local areas of concern.

In U.S. EPA's 1989 Risk Assessment Guidance for Superfund (RAGS), recommended values for use in exposure calculations for ingestion of contaminated fish and shellfish were based on the analysis of meal size conducted by Pao et al. (1982) using data from USDA's 1977-78 NFCS (U.S. EPA, 1989b). The recommended values included an ingestion rate of 113 g/meal (at the 50th percentile) and 284 g/meal (at the 95th percentile). In the 1991 Supplemental Guidance to RAGS, U.S. EPA (1991) proposed using 54 g/day (the mean rate for finfish consumption derived by Pao et al., 1982) for recreational fishers and 132 g/day (the rate at the 95th percentile) for subsistence fishers (Table 13).

U.S. EPA recently completed a draft volume in their guidance series *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* that included a review of fish consumption studies and a list of studies targeting subsistence fishers and recreational fishers (U.S. EPA, 1995a). Many of the studies that have been completed on noncommercial fishers cited by U.S. EPA have been reviewed in this report. U.S. EPA also identified several studies in progress to define consumption patterns and rates for subgroups of subsistence fishers, including Laotian, Hmong, Cambodian, and Vietnamese groups, and a number of Native American tribal communities. U.S. EPA did not derive recommended consumption values from these studies but suggested that the results of specific studies be selected for use on the basis of similarity in target populations. U.S. EPA is also currently revising the Exposure Factors Handbook, and the recommended default values for fish and shellfish consumption rates may be revised based on analyses of more recent studies. The revised version of the handbook is expected to cover many of the consumption studies reviewed in this report.

5. Summary of Sport Fish Consumption Rates

Mean rates for sport fish and total fish consumption by consumers of noncommercial fish and shellfish exceed per capita rates for the overall U.S. population derived from national studies. The average rates of consumption of fish and shellfish by fishing populations may fall within the range of values derived for consumers only based on national surveys. However, it is difficult to compare consumption among fishers to national rates derived for consumers only because so few national consumer studies have been conducted and/or the analyses completed. In addition, the national studies have not adequately addressed consumption of sport-caught fish and shellfish. The estimate of finfish consumption derived by Pao et al. (1982) included consumption of mainly commercially purchased products (*e.g.*, fishsticks, flounder, haddock, and perch) rather than sport fish. U.S. EPA (1995a) recommended that regional studies be used rather than national studies to characterize consumption by recreational and subsistence fishers because the national studies are more likely to mask individual variation and information pertaining to consumption by subpopulations of interest is thus lost.

A number of studies have been conducted on a regional basis that provide information relevant to populations fishing in these regions. Which of these consumption values can be applied to other similar scenarios must be determined based on the characteristics of the population of interest and the particular uses for which the estimated rates are needed. Among the studies conducted regionally on fishing populations, overall mean rates for sport fish consumption only ranged from 12.3 to 63.2 g/day (Tables 11, 12, and 14). Certain subgroups had substantially higher average rates of consumption, as reviewed in the Discussion section below. Full distributional analyses were not conducted in all of the studies and upper percentile rates of consumption were provided in only a few of the studies. Thus it is not possible to summarize the range of values representing upper level consumption rates. Several studies indicated that fishers and other consumers of sport fish and/or shellfish consumed commercial species in addition to sport-caught fish, although only a few studies of fishing populations evaluated total seafood consumption inclusive of commercially available fish and/or shellfish. The overall mean rates for total fish consumption (from all sources) in these studies ranged from 16.1 to 61.3 g/day. (It should be noted that the values representing both the lower and upper ends of this range were derived from different analyses performed on the same dataset.)

Several studies in the Great Lakes region have provided estimates of fish consumption rates in that region. The surveys and analyses conducted on fishing populations using the Great Lakes and other Michigan waters (*e.g.*, West et al., 1992, 1993; Murray and Burmaster, 1994) were the most comprehensive of these studies. Although the results of the Michigan Sport Anglers study were based on a mail survey that targeted licensed fishers only and relied on self-selected respondents, the authors also evaluated differences between respondents and nonrespondents and adjusted the estimated mean consumption rates accordingly. However, the estimates of consumption derived by West et al. included a large percentage of respondents (more than half) who had not eaten any fish during the study period. Murray and Burmaster (1994) provided estimates of consumption based upon actual consumers and used the data obtained in the 1988 Michigan study to construct a distributional analysis of fish consumption in the state.

The analyses performed by Murray and Burmaster (1994) on data from Michigan sport fishers provided results for both sport-caught and total fish consumption for anglers and other adult consumers. Their analyses are comparable to the analyses conducted by Hill and Lee (1995) as discussed below. Murray and Burmaster (1994) calculated an overall mean consumption rate for adult consumers as well as for various groups of anglers and others that consumed sport fish (Table 8). A comparison of these rates shows that consumers of sport fish, and anglers in particular, had higher rates of consumption of fish, on average, compared to the general adult consumer population. A comparison of mean consumption rates of sport fish and total fish by anglers and other consumers of sport fish suggests that anglers and other consumers supplement sport-caught fish with consumption of fish obtained from other (commercial) sources.

The surveys reported by Fiore et al. (1989) and Connelly et al. (1990) used somewhat different methods, calculating the number of meals eaten per year and providing only crude estimates of

actual consumption. The average number of total fish meals reported for anglers in each study was similar (42 and 45 meals/year, respectively). Evaluation of consumption of sport fish alone was notably incomplete, particularly in the New York Statewide survey. Therefore, the usefulness and applicability of the data from these studies for estimating consumption of sport fish are limited.

The angler survey conducted by ChemRisk (1994) provided relatively low values for consumption of sport-caught fish from freshwater bodies in Maine. Given that consumption rates were calculated for selected species obtained from selected freshwater bodies, exclusive of any marine species, the results do not provide estimates of total sport fish consumption but indicate that relatively small quantities of freshwater species were caught and consumed by a select subpopulation of fishers in the state. These rates may be applicable in regions with similar conditions, (*i.e.*, populations fishing in freshwater bodies subject to consumption advisories, seasonal limitations in access and availability of fish, greater availability of saltwater species, absence of high-use populations such as Native American tribes, etc.). The estimates derived from this study are not likely to be representative of freshwater fishers in general.

The information derived from the CRITFC (1994) study provided comprehensive fish consumption data for four Native American tribes consuming fish from the Columbia River Basin and documented fish consumption rates and patterns that may be generalizable for similar Native American populations. Although the findings may only be applicable to select subpopulations, the results are important in geographic areas where these groups comprise a significant portion of the fishing population. The results also demonstrate that fishers near a productive freshwater fishery can obtain and consume fish in amounts at least comparable to what is obtained from marine sources, although special fishing rights of Native American tribes may allow for greater catch.

Fish consumption data collected by Harnly et al. (1997) from residents near Clear Lake, California are pertinent to the small group of individuals surveyed (mostly members of a Native American tribe) and may not be applicable to the general California population or to all California fishers. However, no other study of consumption of sport fish from freshwater bodies in California is available. These data do indicate that certain subpopulations in California consume sport-caught freshwater species at rates that are comparable to, or greater than, the average rates reported for consumption of marine sport fish in the state. The study results also suggested that some sport fishers may also consume commercially available species.

SCCWRP and MBC (1994) compared their results from Santa Monica Bay with those reported by Puffer et al. (1982), and stated that the consumption patterns of the ethnic groups were similar (as discussed in greater detail in the Discussion). Puffer et al. (1982) did not report mean consumption rates, and the overall median rate they reported (36.9 g/day) was higher than the median rate (21.4 g/day) reported by SCCWRP and MBC (1994). However, the methodologies in the two studies were different.

The Santa Monica Bay Seafood Consumption Study (1994) is the largest study to date of California fishers and thus provides the most comprehensive database relevant to sport fishers in the state, particularly those fishing in marine waters. A variety of fishing modes were included in the survey and all seasons were included in the year-long study period. Because respondents reported consumption of fish for a one-month period of time, the variability in frequency of consumption among fishers would more likely be captured than in studies using short recall periods. Interviewers used a fillet model to help anglers describe his or her own consumption, in addition to methods similar to those used by Puffer et al. (1982) in deriving consumption rates based on estimates of the consumable portion weights divided by the number of consumers in a household. Interviewers also used pictures of fish when fish were not in hand to facilitate correct identification of species. Although the reported rates for fish consumption were derived from the amount of fish respondents reported to have consumed, and it is possible that reports of fish consumption used to calculate the rates of consumption were inaccurate due to over- or under-reporting by respondents, a comparison of the results obtained from the two methods used for estimating fish consumption rates showed that the results were similar for most groups. Demographic characteristics of the population and the relationships of these factors to consumption were evaluated. Interviews were conducted in other languages (mainly Spanish) when appropriate in order to achieve greater representation from ethnic groups (although language barriers were still encountered in some cases). A stratified-random sampling design was employed to minimize bias, and a comprehensive survey resulted from the frequent and extensive coverage of fishers in Santa Monica Bay. Although creel surveys and other surveys conducted at fishing locations may oversample the most frequent fishers, the frequency of interviews conducted over a year-long period (combined with the random sampling regime) were likely to have increased the representativeness of the sample population. However, the fish consumption rates derived from this study applied to consumption of Santa Monica Bay sport fish only rather than consumption of fish from all sport and commercial sources. Additionally, the data were derived from reported consumption by the fishers themselves who were principally males. This study avoided the biases inherent to mail surveys which rely on a self-selected sample population of respondents by conducting personal interviews with randomly selected fishers. For all these reasons, the 1991-92 Santa Monica Bay Study is the most representative and best available dataset for estimating sport fish consumption rates among California fishers.

In addition, the similarity in results for the distribution of consumption rates derived from the Santa Monica Bay study and from the Michigan study as analyzed by Murray and Burmaster (1994) suggests that these consumption rates may be generalizable to fishing populations using large marine and freshwater bodies. Ideally, it is preferable to obtain or apply regional, localized data for specific local areas of concern, particularly when the conditions differ in a substantial way. However, when local data are not available, the results from the Santa Monica Bay study may be applicable to other regions in which the populations of interest and other relevant factors are similar.

V. DISCUSSION

The following discussion will include a review of studies identifying particular subgroups of the overall U.S. population that may differ in their patterns and rates of consumption of fish and shellfish. Subpopulations could include subsistence fishers, ethnic groups, age and sex groups, and populations residing in certain geographic regions. Rates derived from several studies were reported by region (Table 3b), race or ethnicity (Tables 7, 9, 10, and 15), and age and sex groups (Tables 16 and 17). In some cases, limited information was available for subpopulations. For example, sample sizes tended to be small for the younger age groups and various ethnic populations included in some of the national surveys. In these cases, the reported differences in rates may be indicators of trends or patterns rather than absolute consumption rates. The discussion also considers consumption rates that apply to fish and/or shellfish obtained from different types of water bodies, including freshwater and marine sources. The discussion of subpopulations includes an evaluation of fish and shellfish consumption rates for California populations. A review of “other issues” provides information about meal or portion size. The section concludes with a discussion of the application of fish and shellfish consumption rates (and potential differences among subpopulations) to the risk assessment process.

A. Trends in Fish and Shellfish Consumption Rates For Subpopulations

Several studies have suggested that fish consumption rates differ for specific subpopulations. Demographic characteristics, such as race or ethnicity, age, and sex, and the relationships between these variables and fish and shellfish consumption rates (and patterns) are described below. Some of the national studies (*e.g.*, Rupp et al., 1980) indicated regional differences in consumption rates that could be influenced by local cultural preferences and/or the types of fish and shellfish that are available in certain regions and at certain times of the year, and the amount of sport or subsistence fishing that occurs in a given region. In addition, as indicated previously, rates may vary within the subset of the population that catches and consumes fish. Some recreational fishers may fish primarily in response to the seasonality of their “favorite” species, whereas other recreational fishers may fish more avidly. Subsistence fishers and recreational fishers may also preserve fish for consumption during nonfishing seasons or other times (Puffer et al., 1982; U.S. EPA, 1995a). Subsistence fishers, by definition, are likely to fish on a regular basis in order to secure food for themselves and their families. Thus, subsistence fishers are typically considered to be high-end consumers.

1. Subsistence Fishers

U.S. EPA (1994, 1995a) considered subsistence fishers to be people who rely on noncommercial fish as a major source of protein, and suggested that subsistence fishers tend to consume noncommercial fish and/or shellfish at higher rates than other fishing populations, and for a greater percentage of the year, due to cultural and/or economic factors. Few studies have specifically targeted fishing populations identified as subsistence fishers (although several studies which U.S. EPA, 1995a, has indicated are currently in progress, or recently completed, are not yet available). The definition for subsistence fishers provided by U.S. EPA is descriptive (and somewhat circular) and does not indicate how to actually identify subsistence fishers in a

population. There are no particular criteria or thresholds (such as income level or frequency of fishing) that definitively describe the group. Additionally, fishers are not always willing to report their income and do not necessarily identify themselves as subsistence fishers. In some of the “subsistence studies” summarized by U.S. EPA (1995a), the respondents indicated that they did not consider themselves subsistence fishers although they relied on the fish they caught as a major component of their diet. Thus, it may not be possible to define or represent subsistence fishers in any quantifiable way.

U.S. EPA (1995a) suggested that Native Americans, lower income urban populations (especially Blacks), and Asian-Americans are often subsistence fishers, and described some of the difficulties in characterizing these subpopulations. “Unless surveyed specifically, subsistence fishers are likely to be underrepresented in available surveys. Fish licensing still remains one of the most common survey methods in practice, and subsistence fishers may not have registered for fishing licenses for a variety of reasons. They may be unaware of the requirements, the licenses may be too expensive, and Native Americans are not required to use fishing permits on their own lands.” In addition, fishing may be permitted without a license in certain locations. U.S. EPA did not indicate the basis of the assumption that subsistence fishers do not obtain fishing licenses and it is unclear what portion of “subsistence fishers” do not have licenses. In regions where consumption studies have been limited to licensed fishers, this concern may be more relevant than in areas where different methodologies were used to obtain consumption data (*e.g.*, the Santa Monica Bay Seafood Consumption Study).

These problems with defining subsistence fishers contribute to difficulties characterizing consumption of fish and shellfish by the subpopulation of subsistence fishers. The Santa Monica Bay study asked respondents to report their annual household income. Relatively few respondents reported annual household income in the lowest income brackets (less than \$5000 or between \$5000 and \$10,000) and it is not possible to determine whether any, some, or all of these people, or those with higher income, were subsistence fishers. Furthermore, although the median rate of consumption was higher for the lowest-income group, the mean and upper percentile rates were higher for the higher-income groups. The study also asked fishers about their frequency of fishing and found that roughly two percent of the respondents reported having fished every day for the prior month. However, a consumption rate was not determined separately for this group. Additionally, although subsistence fishers would be expected to fish as frequently as every day, other fishers (*e.g.*, retired persons) may also fish frequently. On the other hand, if at least some subsistence fishers were included in this survey, then the (upper percentile) consumption rates that were calculated would have encompassed this subpopulation.

The study conducted at Clear Lake, California, although small, represented about half (46%) of the Native American Elem population residing near Clear Lake, and suggested that approximately half of the people in this community consumed no sport fish while those that did eat sport fish consumed them at relatively high rates. The mean level of intake of sport-caught fish by residents (consumers) near Clear Lake was similar to the mean rate calculated for four Native American tribes represented by the CRITFC (1994) study. The average rates of

consumption of sport fish determined for fishers in the Elem tribe at Clear Lake and four tribes in the Columbia River Basin were 60 g/day and 63.2 g/day, respectively. The rate determined at the 95th percentile in the CRITFC study was 170 g/day. Because the study in the Columbia River Basin is regarded as a comprehensive and well-conducted study (U.S. EPA, 1995a), it is likely to provide reliable estimates of consumption by Native American subsistence populations residing near productive fishing waters. CRITFC (1994) described the communities represented in the study as subsistence fishers and provided the following viewpoint which may serve to describe subsistence fishers. “The importance of fish, especially salmon, to the tribes cannot be overstated for the fishery resource is not only a major food source for tribal members, it is also an integral part of the tribes’ cultural, economic and spiritual well-being.” However, not all subsistence populations are expected to be Native Americans, and the communities represented in these studies of Native American tribes may be very different than urban or other subsistence fishers.

Although the mean rates of consumption in these two studies of west coast Native American fishers were higher than the mean rate calculated for fishers in Santa Monica Bay (60 and 63.2 g/day compared to 49.6 g/day), the upper level intake rates were comparable. SCCWRP and MBC (1994) reported an upper level intake of 107.1 g/day at the 90th percentile, and Hill and Lee (1995) estimated the 95th percentile to be 160.7 g/day for fishers in Santa Monica Bay. These results suggest that subsistence fishing populations may be covered by the use of upper level intake rates in exposure calculations. Additionally, the mean consumption rate derived from the CRITFC (1994) study, 63.2 g/day, may represent an average consumption rate for subsistence populations similar to those surveyed, although the tribal fishers surveyed may not be representative of other types of subsistence fishers such as those fishing in urban areas. U.S. EPA (1995a) reported that a few studies (not yet available) have shown exceptionally high levels of intake for certain subsistence populations. Therefore, additional information may be needed to evaluate populations potentially having considerably higher rates of consumption of sport fish and/or shellfish. As one example, subsistence economies in Alaska were described by Wolfe and Walker (1987) in which annual harvests of fish in some communities provided up to 1239 pounds per capita (equivalent to 1540 g/day).

In the Native American tribal populations surveyed in the CRITFC (1994) study and presented as subsistence fishers, the average number of fish meals eaten per week by adult consumers was 1.85 for the entire year. During the two months of the year with the highest consumption, the average number of fish meals per week increased to 2.93. The maximum number reported was 30 meals per week, for only one person. Approximately nine percent of the respondents reported eating four or more fish meals per week, and about four percent reported consuming fish seven or more times per week.

One of the notable findings of the Santa Monica Bay study was that fishers with the highest income had the highest mean rate and upper (90th) percentile rate of consumption. Therefore, although estimating exposure to chemical contaminants in fish and shellfish is important for subsistence populations which are likely to include individuals that consume above-average

amounts of fish and shellfish, subsistence fishers do not necessarily consume more fish than other avid (and successful) fishers. All high-end consumers, including fishers with relatively high income, may be subject to exposure to chemical contaminants from consumption of sport fish and/or shellfish. Thus, exposure calculations using an upper percentile or bounding estimate are important to describe *all* high-end consumers. In addition, the fish species that are commonly caught from boats can differ from those taken on shore, and may include larger predatory species which may have accumulated higher levels of chemical contaminants.

Despite the current lack of empirical data to support the idea of a subsistence fisher as one who relies on sport-caught fish and/or shellfish for sustenance and/or one who consumes sport fish and shellfish at rates which exceed those of other avid consumers, the concept remains important from a public health perspective. Subsistence populations, particularly any which do not speak or read English, are likely to have reduced access to information about contaminated fish, and people with limited economic resources may have fewer alternative sources of protein. Some subsistence fishing populations may be comprised of a large proportion of women of child-bearing age and/or children who could be more susceptible to adverse health effects from contaminants (Hutchison and Kraft, 1994). For these reasons, it is essential to develop ways to define potentially at-risk subsistence populations and to provide risk communication specifically targeted toward the population(s) of concern.

The concept of a “subsistence fisher” lumps together ethnically diverse peoples with different fishing access, preferences, and success on potentially different water bodies. Because of the difficulty in defining and targeting “globally defined” subsistence populations, it is especially important that subsistence fishing populations be locally defined, characterized, and targeted. Insofar as a quantifiable working definition of subsistence fishers is lacking, and few data are currently available to characterize fish and shellfish consumption for subsistence populations, a more thorough evaluation of consumption rates applicable to subsistence fishers requires both additional data and guidance for obtaining such data.

2. Consumption Rates by Racial or Ethnic Group

Hu (1985) evaluated how various sociodemographic and economic factors, including per capita income, family size, occupation, age, race (Black, White, and other), religion (Catholic, Jewish, Protestant, and other), education level of the head of household, and geographic region, related to seafood consumption. Hu compared data from four national studies conducted between 1970 and 1981 and stated that “in general, the Blacks and Orientals consume more than Whites.” However, he added that over time, a larger percentage of Whites were eating fish, especially finfish. Hu reported demographic differences such as higher intake of certain types of seafood (such as shrimp) by certain ethnic or racial groups and by variables such as income and region. Other studies have also reported varying fish consumption rates for certain species of fish by specific ethnic groups (Javitz, 1980; West, 1992, 1993; SCCWRP and MBC, 1994).

Javitz (1980) derived mean consumption rates by age and sex, race (White, Black, Oriental, and other), and other demographic variables. Javitz concluded from the 1969-70 Market Facts Survey data that Blacks and Jews had higher mean consumption rates than other subpopulations, and he reported that based on the NPD data, Orientals reached the highest 95th percentile rate. Mean per capita consumption rates based on the NPD data were 14.2, 16.0, and 21.0 g/day for Whites, Blacks, and Orientals, respectively (Javitz, 1980; Table 15). These differences in average rates of consumption among groups were small; the higher-consuming group was less than two times greater than the lower-consuming group. Because these values represented per capita rates, they may be useful for comparing trends among groups but are not likely to provide accurate estimates of actual consumption rates by consumers.

USDA (1983) also collected information on age, sex, race (White, Black, or other), education, occupation, income, and employment status. Mean fish and shellfish consumption rates were reported in summary tables by race (Black or White), income, and degree of urbanization (central cities, suburban, and nonmetropolitan). Overall mean per capita consumption rates did not vary by income level by more than one gram per day. Blacks had higher average rates of consumption than Whites (15 g/day compared to 11 g/day). Consumption rates were higher in central cities (14 g/day) compared to suburban (12 g/day) and nonmetropolitan (10 g/day) areas. These findings, which were also calculated on a per capita basis, show relatively small differences among groups.

The Santa Monica Bay Seafood Consumption Study (SCCWRP and MBC, 1994) reported that of the “identifiable ethnic groups,” the Other group had the highest mean consumption rate (137.3 g/day/person), and upper decile rates were highest for Whites, Asians, and Other (112.5 g/day, 115.7 g/day, and 173.6 g/day, at the 90th percentile, respectively). The Other group, which included a small number of people (14) of mainly Pacific Island origin, was significantly different from Filipinos, Japanese, and Whites; and Whites were significantly different from Hispanics. On the basis of average rates of consumption, the highest consuming group (Other) exceeded the overall mean by almost three times, and exceeded the lowest consuming group (Hispanic) by nearly five times. The authors also reported that relative to the population around Santa Monica Bay, more Asians, Whites, and other ethnicities (but not including Hispanics or Blacks) fished in the bay.

Puffer et al. (1982) also compared subpopulations of fishers in the Los Angeles area. The report noted that most anglers that were interviewed were White, and that Orientals (Samoans) and Mexican-Americans may have been underrepresented due to language differences. Statistical tests for differences among group median rates of consumption showed that consumption rates were significantly higher for Orientals/Samoans (70.6 g/day/person). Also, median consumption rates were lower for Blacks (24.2 g/day/person) and Mexican-Americans (33.0 g/day/person) than Whites (46.0 g/day/person) but statistically significant differences were not indicated. Puffer and colleagues also found ethnic differences in the frequency of fishing in that significantly different proportions of ethnic groups accounted for frequent versus infrequent fishers.

SCCWRP and MBC (1994) compared their results from Santa Monica Bay with those reported by Puffer et al. (1982) and stated that the consumption patterns of the ethnic groups were similar. In each study, certain Asian subgroups (Pacific Islander and Oriental/Samoan, respectively) were the highest consuming group, and Hispanics or Mexican-Americans had lower consumption rates. However, in the earlier study, Blacks had the lowest median consumption rate (24.2 g/day), with Mexican-Americans somewhat higher (33 g/day). In the 1991-92 study, Hispanics had the lowest median (16.1 g/day) and Blacks had a median rate of 24.1 which was higher than the overall median rate (21.4 g/day). Whites in both studies had median consumption rates in the mid-range, and consumption rates for Asian groups, depending on how they were defined (which subgroups were included), were similar to, lower than, or higher than the rate calculated for Whites (see further discussion below).

The median rates of consumption reported for Blacks by the Santa Monica Bay study (SCCWRP and MBC, 1994) and by Puffer et al. (1982) for the same geographic area were almost identical, although in the first case, the consumption rate for Blacks was reported to be the highest median rate, and in the second case, reported to be the lowest median rate among racial and ethnic groups. This difference underscores the importance of not only obtaining the appropriate regional or site-specific data, but also understanding factors such as how the population groups surveyed were defined, what analyses were performed on the data, and the relevance of these factors to the population of concern. A comparison of the findings in each of these studies suggests that patterns of fish consumption are highly variable within and among groups, and possibly over time. (It is possible, although untested, that differences in the findings of each study regarding consumption patterns of ethnic groups may have resulted from sampling at different times, since the two studies were conducted approximately ten years apart.) Further comparison of the two studies is hindered by the fact that Puffer et al. (1982) only derived median rates of consumption, and because the methodologies were so different in each study, comparisons may not be illuminating.

The San Diego Bay Health Risk Study (1990) also reported trends for different rates of consumption of fish and shellfish among ethnic groups. They reported that Asians and Filipinos had the highest consumption rates, compared to Whites and Hispanics, and also represented larger proportions of sport fish consumers. They noted differences in fishing success among ethnic groups, with Asians and Filipinos having the highest success rate, which could affect the amount of fish available for consumption (depending on the number of consumers sharing the catch). They also reported that the parts of fish consumed varied by ethnicity. However, sample sizes were too small, especially for Asians and Hispanics, to provide reliable estimates of the consumption rates for these subpopulations.

Landolt et al. (1985) reported “significant findings in ethnic differences” among fishers in Puget Sound, more so with respect to the patterns and characteristics of fishing populations than fish consumption rates. For example, Blacks fished more from bridges whereas Whites fished more on boats. The number of family members fishing and eating fish differed among ethnic groups

as did fishing success; each of these measures was higher for Asians. The frequency of encounter (and thus being interviewed) was greater for Whites. Based on estimates of the edible portions of catch, Landolt and colleagues determined the total amounts of fish consumed using geometric means for non-U.S. born Asians, U.S. born Asians, Whites, and Blacks to be 10, 11, 11, and 9 kg/yr, respectively. Landolt et al. noted that subpopulations fished in response to favorite species. Therefore, consumption rates could vary based on the seasonality and availability of preferred species. The differences in consumption rates among ethnic groups were small, although trends among groups may be indicated by the results. In addition, variations in the patterns of consumption of fish and shellfish by various ethnic groups, and differences in fishing behavior were well characterized by this study.

West et al. (1989a, 1992) surveyed anglers in Michigan to determine potential risks to subpopulations. Rates of consumption were compared among different subpopulations and demographic factors such as race, income, age, level of education, and size of town were examined. They found marginally nonsignificant differences for ethnic groups and reported mean rates of consumption (in g/day/person) as follows: 17.9 for Whites, 19.8 for other minorities, including Hispanics, 20.3 for Blacks, and 24.3 for Native Americans. Although West et al. (1989a) reported that the highest fish consumers were minorities and low-income groups, statistical analyses showed that race, when controlled for age, became nonsignificant (West et al., 1992). Thus, the interaction of certain demographic factors appeared to be important to the outcome. As another example, fish consumption among Whites was consistent across income, whereas it was highest for middle-income Blacks, and higher for low-income and high-income Native Americans than middle-income Native Americans. A significant positive relationship between the number of years anglers lived in Michigan and fish consumption rates was also found, especially among Blacks. These analyses show that the patterns of fish consumption can vary within and among ethnic groups, and the results underscore the importance of considering regional or other locally specific factors when determining the most appropriate rates for subpopulations.

A comparison of different analyses performed on the same data reveals the importance of the definitions of ethnic groups to the results and conclusions that are drawn. For example, Hill and Lee (1995) grouped the “Other” category (consisting mainly of Pacific Islanders) from the Santa Monica Bay study together with the Asian groups. SCCWRP and MBC (1994), on the other hand, evaluated the data with “Other” considered separately. Because Pacific Islanders had significantly higher consumption rates than any group, combining them with other Asian groups would appear to show that Asians also had significantly higher rates when, in fact, the remaining Asian fishers, when grouped together, were not significantly different from Whites in average fish consumption. Similarly, Puffer et al. (1982) grouped together Samoans and Asians and found that this group had a higher rate of consumption, most likely as a result of the high rates reported by the Samoan portion of the sample population.

The importance of clearly defining the target population is further apparent when reviewing additional analyses performed on the Santa Monica Bay dataset by Hill (1995). In this analysis,

mean consumption rates among ethnic groups were compared and each Asian group was considered separately rather than in combination with other Asian subpopulations. The results showed that some Asian groups (*i.e.*, Vietnamese and Japanese) had average consumption rates well below the overall mean (27.9 and 34.5 g/day, respectively, compared to 49.6 g/day). The higher consuming Asian groups included Filipino and Other (Pacific Islanders). Chinese and Koreans had average consumption rates comparable to Whites and to the overall mean (Table 9). Hill (1995) reported that the results of an analysis of variance (ANOVA), with the Other group removed, showed no significant differences among ethnic groups, probably due to the large amount of variability within groups.

In summary, several studies have found differences in consumption rates among ethnic subpopulations. The trends for particular ethnic groups are not consistent across studies. However, it is difficult to compare results across studies as the methodologies (and definitions of target groups) used in the surveys are different. This problem was exemplified by the differences found for specific ethnic groups fishing in the same region (Santa Monica Bay), as discussed above. The importance of obtaining up-to-date, site-specific data whenever possible, particularly for characterizing subpopulations of interest, is evident.

Consumption studies in progress may contribute further information about ethnic subgroups. Based on data from the studies that are currently available, differences in average rates of consumption among ethnic groups appeared to vary within the range of a five-fold difference. For example, average consumption rates for ethnic subgroups in the Santa Monica Bay study ranged from 28.2 g/day (Hispanics) to 137.3 g/day (Other, mainly Pacific Islanders). Additionally, the highest consuming subgroup (Other) exceeded the overall mean rate (49.6 g/day) by roughly three times. Variability in patterns related to fish and shellfish consumption were also apparent in some studies and could be particularly important to risk communication.

3. Consumption Rates by Age and Sex

Rupp et al. (1980) reported average annual per capita consumption rates based on the NPD dataset for each of three age groups: children, aged 1-11 years, teens, aged 12-18 years, and adults, aged 18-98 years (2.1, 3.48, and 5.75 kg/yr, respectively). The annual amounts correspond to 5.8, 9.5, and 15.8 g/day, respectively (Table 16a). Although the rate of consumption of fish and/or shellfish increased with age, the rates were not adjusted for differences in body weight.

Javitz (1980) summarized values calculated by age and sex based on the NPD dataset and reported that the mean and upper 95th percentile consumption quantities of fish increased with each age group up to age 60 in women (19.5 g/day for the mean, and 50.1 g/day for the 95th%) and age 70 (24.4 g/day for the mean, and 61.1 g/day for the 95th%) in men, with subsequent decreases in the amount consumed after reaching these ages (Table 16a). Javitz reported that the amounts of fish consumed were consistently lower for females than for males. The overall mean consumption rates were 13.2 g/day for females and 15.6 g/day for males. Again, whether these

differences could be accounted for by differences in body weight was not evaluated. However, dividing these overall mean consumption rates by the average body weights determined for adult women and men of 65.4 kg and 78.7 kg, respectively (Finley et al., 1994), shows that both females and males consumed, on average and on a per capita basis, 0.2 g/day per kg body weight.

Miller and Nash (1971) reported “positive indications that older people are more disposed to eating fish products” such as oysters, clams, and scallops based on the 1969 Market Facts Consumer Panel Survey. They suggested that age differences may have been related to differences in income, although consumption of shrimp appeared to be evenly distributed across age groups regardless of income level.

Per capita consumption rates were reported by age and sex for the 1977-78 NFCS (USDA, 1983; Table 16b). Pao et al. (1982) also presented fish consumption quantities for consumers by age and sex groups based on the 1977-78 NFCS data (Table 17). Males were consistently higher than females in mean rates of consumption (and in meal size) for fish and shellfish, finfish, tuna, and shrimp. Sum totals by sex were not provided. Pao and colleagues reported that consumption quantities increased consistently with age, but as in many other cases, no consideration was given to differences in body weight. Because the report did not include average body weights for each age and sex category, it is difficult to evaluate whether the mean consumption rates, if adjusted for body weight, would be equivalent.

Preliminary reports on the data obtained from the 1989-91 CSFII (USDA, 1994) presented per capita fish intake by age and sex and generally showed increases with age in consumption rates for males and females, with more variability among adult age categories (Table 16c). Males were consistently higher than females in fish intake, with the exception of consumption of fish by men and women over 80 years, which could be influenced by the respective numbers of consumers in the elder age category.

Murray and Burmaster (1994) evaluated consumption rates for various subgroups of adult consumers surveyed in the 1988 Michigan Sport Anglers Fish Consumption Survey. They reported mean rates for total fish consumed by males and females as 47.8 and 42.3 g/day, respectively.

Puffer et al. (1982) reported that individuals over 65 years had the highest median rate of consumption (113.0 g/day). This rate was approximately three times greater than the overall median rate in the Los Angeles study (36.9 g/day) and appears to represent a relatively higher consumption rate for fish and shellfish consumers in the eldest age category compared to other studies that evaluated consumption by people in this age category. This relatively high consumption rate for older anglers is not likely to be explained by differences in body weight.

West et al. (1992) found that differences by age in consumption rates were statistically significant. Three age categories were compared and the results showed that people over 50 had significantly higher rates of fish consumption. Average consumption rates in the eldest category

(51-91 years) were between 1.2 and 2.2 times greater than average rates in the youngest category (1-30 years); the middle-aged groups (31-50) had mid-range consumption rates. Although the youngest age category included children, these differences are not likely to be fully attributable to body weight. In addition, certain demographic variables (age and race) were jointly operative. For example, older Blacks (over 50 years) had “very high rates of fish consumption” (31.9 g/day/person). Consumption rates for Native Americans were highest in the middle age group, 31-50 years. Thus, different age groups combined with different minority groups to produce the highest consuming subgroups (West et al., 1992). However, as discussed above, statistical analyses of the 1991-92 dataset reported by West et al. (1993) found no significant relationship between age and rates of consumption.

In summary, the available data indicate that consumption rates (g/day) tend to increase with age, particularly for adults compared to children, and males tend to consume more fish and shellfish (g/day or per meal) than females. However, because body weight was not presented in the results of these surveys, it is not possible to evaluate to what extent consumption rates may differ on a “per kilogram of body weight” basis. In some cases, although not all, the differences in rates of fish consumption that have been reported are likely to correspond to differences in body weight. Future studies of consumption rates ideally should investigate the correlation between body weight and consumption rate. It is recommended that exposure assessments consider sex and age-specific consumption rates when available. However, few studies of fishing populations have obtained data for age groups or by sex. In the absence of these data, potential risks to subsets of the population (*e.g.*, children) can be evaluated by using a multiplier (alternate consumer body weight divided by default adult body weight) in exposure calculations (U.S. EPA, 1994).

There is limited evidence that some elderly fishers consume greater than average quantities of sport fish. In situations where a particular subgroup (*e.g.*, older Black anglers in Michigan or elderly fishers in Los Angeles) consumed greater quantities of fish and/or shellfish, the average rates varied on the order of a two-fold to three-fold difference. These higher consuming subgroups are likely to be included within the upper percentile consumption rates derived from a distributional analysis.

4. Differences in Consumption Rates by Geographic Region

Rupp et al. (1980) reported the amounts of fish consumed in nine regions of the U.S. based on the NPD survey data. They reported that regional differences were most apparent for freshwater and shellfish species. For example, consumption of freshwater species was greater in inland areas than coastal areas, and shellfish consumption was lower in certain inland regions. Javitz (1980) indicated that according to the NPD data, the mean and 95th percentile rates were highest for large central cities with population size exceeding two million (19.0 g/day and 55.6 g/day, respectively) compared to the mean and 95th percentile rates for areas outside central cities with population size between 50,000 and 250,000 (11.3 g/day and 31.7 g/day, respectively).

Miller and Nash (1971) focused on consumption of shellfish and reported regional differences or preferences by species. For example, the amounts of oysters consumed in the U.S. were greatest in the South Atlantic and Pacific regions, consumption of clams was greater in New England, the Mid Atlantic, and Pacific regions, and crabs were consumed in the largest quantities in the Pacific states. Consumption rates for preferred species could also be influenced by seasonal factors such as differences in the times of harvest. Nash (1971) found that per capita rates of consumption (in pounds per year) also varied by region, ranging from 7.9 to 17.6 pounds/year and being lowest in the West-North-Central states.

West et al. (1992) found a significant relationship between the size of town and rate of consumption of fish. However, the relationship was nonlinear, and they found significant interactions between race or ethnicity and place of residence. These types of regional differences and interactions among variables indicate the importance of data that apply to the specific geographic location and population(s) of interest. These data should be considered when available.

5. Consumption Rates by Type of Water Body: Freshwater versus Marine

Data from the 1973-74 NPD survey have been used to differentiate consumption rates for freshwater and marine fish. Using the NPD data, Ruffle et al. (1994) determined mean national per capita intake of freshwater fish and marine fish to be 1.48 g/day and 10.68 g/day, respectively. Stephan (1980) utilized the species-specific consumption data included in the NPD dataset to differentiate between marine and nonmarine species. He used the overall mean fish consumption rate for consumers of 14.3 g/day calculated by Javitz (1980) and adjusted it to derive a national per capita rate of 13.4 g/day. Based on his analysis of marine and nonmarine species in the NPD dataset, he then calculated a mean per capita consumption rate of 6.5 g/day for nonmarine (freshwater and estuarine) fish and shellfish species and 6.9 g/day for marine species.

The values derived by Ruffle et al. (1994) were based on per capita estimates reported by Rupp et al. (1980) in which only about 14% of the population surveyed were reported to be consumers of freshwater finfish (as opposed to 90% of the population reporting consumption of marine finfish). In contrast, the results presented by Stephan (1980) were based on analyses of the type of fish reportedly consumed. Stephan's estimates suggested that marine and freshwater consumption rates were roughly comparable. Stephan (1980) pointed out that differentiating marine and freshwater sources can be difficult because some studies do not indicate the type of fish consumed, or do not do so adequately, and additionally, some researchers classify estuarine species with freshwater whereas others include them with marine species. Another difficulty with the data obtained in the NPD survey is that consumption of sport fish and shellfish could not be distinguished from commercially obtained species, and the amounts reported are likely to include large, as well as variable, percentages of commercial fish and shellfish.

Rupp et al. (1980) reviewed two studies of freshwater anglers in addition to the 1973-74 NPD dataset: one from the Columbia River conducted in the 1960's and one from Lake Michigan from the early 1970's. Although the consumption rates derived from each of these two regional studies were comparably high^o, Rupp et al. (1980) reported a relatively low per capita rate of 1.2 g/day for freshwater fish consumption based on the NPD national data. They also reported, as indicated previously, that only 14% of the national survey population consumed freshwater fish. Therefore, the rates per person would actually be relatively high for consumers of freshwater species.

As indicated previously, because the percentage of users is highly variable for freshwater and marine fish species, use of per capita estimates to differentiate rates of consumption for fish obtained from freshwater and marine water bodies may not provide realistic estimates of the rate of consumption by consumers for each of these types of water bodies. However, Rupp et al. (1980) also presented limited information for consumers. The total annual amount that they reported for consumption of freshwater species (3.41 kg/yr) was similar to the amount estimated for marine species (approximately 3.52 kg/yr); these estimates were derived on a per capita basis for "consumers only." Although it is not possible to discern what proportions of the population consumed either or both freshwater and marine species, the "per capita" consumer rates appear to be roughly comparable for fish obtained from each type (freshwater and marine) of water body. As noted above, these rates are inclusive of commercial species.

Consumption rates for anglers and other consumers of sport-caught freshwater fish species have been estimated from studies conducted in several regions of the U.S. including Michigan (West et al., 1989a, 1992, 1993), Wisconsin (Fiore et al., 1989), New York (Connelly et al., 1990), and Maine (ChemRisk, 1992). Ebert et al. (1994) reviewed numerous studies that targeted fishing populations consuming freshwater species, discussed the sources of differences in the estimated rates of consumption, and emphasized the importance of comparing like studies. They claimed that the source of fish is a key parameter having significant impact on the consumption rate derived; if the reported amount of fish consumed is based on fish obtained from all sources (commercial, gift, and sport; and from multiple, as opposed to single, water bodies), one would expect a higher amount and rate of consumption than if consumption amounts and rates were derived only from sport-caught fish obtained from a single water body or from any other single source (Ebert et al., 1994). They also proposed that the type of water body used by fishers is one of the factors likely to vary by region. Despite their admonition not to compare dissimilar studies, Ebert et al. (1994) compared a number of studies that used different methodologies to derive freshwater fish consumption rates. Most of these studies relied on mail surveys or creel surveys to obtain annual numbers of sport-caught fish meals which were then multiplied by an assumed meal size (which was reported in only a few cases and may have varied among studies) to derive a consumption rate. Reported mean consumption rates ranged from 3.7 to 21.8 g/day

^o The mean and maximum intakes were approximately 8 g/day and 90 g/day for the Columbia River study, and 45 g/day and 323 g/day for Lake Michigan fishers.

for fish caught from multiple freshwater bodies in Maine, Michigan, Wisconsin, New York, and Ontario.

Fiore et al. (1989) surveyed anglers in Wisconsin and determined the mean number of fish meals per year for both sport and commercial fish. Although the study did not specifically target daily consumption, they estimated consumption rates based on the assumption that meal size was eight ounces, and determined daily mean fish consumption rates to be 12.3 g/day for sport fish, 13.8 g/day for commercial fish, and 26.1 g/day for both sources or total fish consumption. The authors noted that, because fish consumption advisories were in place during the survey, consumption rates were likely to have been lower than usual. However, even if consumption of local sport fish was reduced, nearly half of the daily intake (on average) was from freshwater (sport-caught fish) sources.

Connelly et al. (1990) surveyed anglers in New York state to determine the number of fish meals consumed per year. They determined that sport fishers in New York consumed about 50% more than the national average, assuming an eight-ounce meal size. They reported annual consumption by statewide anglers to be 45.2 meals per year or 10.1 kg/yr which corresponds to 27.7 g/day. The number of sport fish meals, either freshwater or marine, was not included in the report. Therefore, it is difficult to assess the portion of fish consumption attributable to sport-caught fish and freshwater species, in particular.

ChemRisk (1992) conducted a mail recall survey asking licensed anglers in Maine to report the numbers and sizes of fish harvested for consumption from Maine freshwater bodies during ice fishing and open water fishing trips. They reported a mean rate of consumption of 6.5 g/day for fish obtained from freshwater bodies, assuming that the catch was shared equally among a mean household size of 2.5 persons. The results applied strictly to freshwater sport fish and, thus, do not provide comparisons of consumption rates from both marine and freshwater sources. The authors suggested that freshwater consumption rates in Maine, based on their findings, were considerably lower than consumption rates reported from other regions of the U.S. as well as values recommended by U.S. EPA. The authors also noted that low rates of consumption of freshwater species in the state were not surprising given the greater availability of saltwater species (both commercially and recreationally).

West et al. (1989a, 1992) surveyed consumption by licensed anglers in Michigan but did not differentiate consumption rates for all types of fish (sport-caught, market, restaurant, and gift) included in their initial survey. In the subsequent year-long study, West et al. (1993) determined consumption rates for both sport-caught fish and total fish consumed. They reported an adjusted mean rate 14.5 g/day for sport fish which would consist entirely of freshwater species (obtained from the Great Lakes or waters flowing into them). The overall mean rate for total fish consumed could include both freshwater and marine species. Thus, it is not possible, with these data, to compare consumption of freshwater and marine species.

Murray and Burmaster (1994) used the Michigan data obtained in the initial 1988 study and estimated that adult consumers of self-caught (freshwater) fish averaged 42.3 g/day. Additionally, they reported mean rates for consumption of sport-caught freshwater fish by anglers as 45.0 g/day for self-caught fish in general, and 40.9 for anglers consuming fish from the Great Lakes, in particular. These rates are roughly comparable to the overall mean consumption rates of 46.4 g/day and 49.6 g/day derived by Hill and Lee (1995) and SCCWRP and MBC (1994), respectively, for anglers in Santa Monica Bay. In addition, upper percentile rates of consumption were roughly similar, although consumption at the 95th percentile in the Michigan study was closer in value to the 90th percentile rate in Santa Monica Bay (98 g/day for consumption of sport fish by anglers in Michigan and 107 g/day for anglers in the Santa Monica Bay survey).

The Santa Monica Bay Seafood Consumption Study (1994), as analyzed by Hill and Lee (1995) and the 1988 Michigan Sport Anglers Fish Consumption Study, as analyzed by Murray and Burmaster (1994), were comparable in many study parameters and in analytical evaluation and, thus, can be used to compare sport fish consumption rates from marine and freshwater sources. Among the regional studies conducted on fishing populations, these two were the most comprehensive and the results are considered here to be the most reliable. The similarity in rates for adult consumers of sport-caught fish derived from each of these analyses suggests that sport fish consumption rates are likely to be comparable for both marine and freshwater bodies.

Overall, the range of consumption values reported for each type of water body, freshwater and marine, were comparable in regional studies of fishing populations. The values reported for mean consumption rates of sport-caught fish ranged up to 50.2 g/day, and 63.2 g/day for Native American fishers, for freshwater fish and up to 49.6 g/day for marine and estuarine fish. Additionally, the fish consumption rates derived from two comprehensive studies, one based on fishers using a freshwater source (Great Lakes) and the other based on anglers using a marine water body (Santa Monica Bay), support the premise that consumption rates for fishers using roughly comparable freshwater and marine water bodies are equivalent. Although freshwater fish consumption rates may be lower than marine fish consumption rates on a national per capita basis, for consumers of freshwater species, rates of consumption are likely to be comparable to rates for marine species depending on the specific characteristics of the water body and the population fishing from it. A comparison of consumption rates for fish obtained from different types of water bodies would need to consider factors such as productivity and seasonality, especially when the water bodies are grossly dissimilar, and other factors such as the amount of effort expended by the fishing population or portions thereof. Thus, regional or population-specific data are preferred when it is possible to obtain them, provided these data are accurate and relevant. However, in general, for exposure assessments in which potential risks to consumers from consumption of sport-caught fish are to be evaluated, the available data do not support using different rates of consumption for fish obtained from marine and freshwater bodies.

B. Fish and Shellfish Consumption Rates for Populations in California

1. Sport Fish

As indicated previously, the Santa Monica Bay Seafood Consumption Study provides the best available dataset for evaluating consumption by California sport fishing populations. The overall median, mean, and 90th percentile rates of consumption derived from this study were 21.4, 49.6, and 107.1 g/day, respectively (SCCWRP and MBC, 1994). Hill and Lee (1995) derived a consumption rate of 160.7 g/day at the 95th percentile. Consumption rates reported for specific subgroups were variable, ranging from 28.2 g/day to 137.3 g/day for mean rates of consumption (SCCWRP and MBC, 1994; Table 9). Therefore, because a single value is not likely to provide the best estimate of consumption for the population as a whole, it is recommended that the distribution be represented by using the median, mean, and an upper percentile rate to define consumption of sport fish by fishing populations in California. In order to encompass all potential high-consuming ethnic groups and/or subsistence fishers, it is recommended that the intake rate at the 95th percentile be used to reflect the upper bound estimate of consumption rates. It should be noted that the results from the Santa Monica Bay study were based mainly on consumption of finfish as opposed to shellfish, although some fishers in the state may seek invertebrate species rather than fish. Consumption rates for shellfish will be discussed below.

2. Commercial Fish

Studies that specifically address consumption of commercially available fish and/or shellfish by populations in California are lacking. National estimates of consumption of commercial fish and shellfish by the general population (particularly those derived from the most current studies, once the results are available) can be applied to consumers in California who eat commercial species only. Additionally, several studies of fishing populations in the U.S. have evaluated both sport and total (including commercial) fish consumption. These studies showed that fishing populations consumed both sport and commercial fish and shellfish. For example, Murray and Burmaster (1994) determined mean rates of consumption for anglers (eating Great Lakes fish) of 40.9 g/day for Great Lakes fish and 61.3 g/day for total fish. The difference amounts to roughly 20 g/day. The difference between sport fish and total fish consumption among other categories analyzed by Murray and Burmaster (*e.g.*, anglers and others that ate self-caught fish) ranged from 8.1 to 20.4 g/day at the median, 7.9 to 20.4 g/day at the mean, and 8.1 to 42.3 g/day at the 95th percentile rate (see Table 8). These limited data suggest that estimates of consumption rates for sport-caught fish and shellfish may not address the consumption of commercial species by fishers and others who supplement their catch.

The distribution determined for sport fish consumption from the Santa Monica Bay study is similar to the distribution derived by Murray and Burmaster (1994) for consumption by anglers in Michigan, although Murray and Burmaster also calculated rates for total fish consumption. It is likely that fishers and others that consume sport fish in California also consume fish and/or shellfish that is purchased commercially. Therefore, estimates used for consumption of sport fish

by California anglers (or others consuming sport fish) should be increased to account for the consumption of commercially available species in addition to sport-caught fish. However, data are not available to use to derive a distribution that describes total fish consumption for fishers and other consumers of sport fish in California. Based on the data obtained from the study of anglers in Michigan, intake of commercial fish and shellfish by consumers of sport fish was at least 8 g/day and approximately 20 g/day on average. The difference between sport fish and total fish consumption may be even greater than 20 g/day at upper levels of intake, as suggested by Murray and Burmaster's analysis. It is not possible to determine from these limited data whether total fish consumption is correlated with sport fish consumption and if there is a correlation, whether it is a positive or an inverse relationship. As a result, only an average amount, 8 g/day at a minimum and 20 g/day as a more conservative estimate, can be recommended to be added to sport fish consumption rates to describe total fish and shellfish consumption by consumers of sport fish and shellfish in California.

3. Shellfish

The mean national per capita rates reported for shellfish consumption ranged from 2.1 to 3.6 g/day (Miller and Nash, 1971; Ruffle et al., 1994). Ruffle et al. (1994) also reported shellfish consumption rates by region. The highest regional per capita rate was 6.2 g/day in New England. The Pacific region ranked third with an estimated 4.1 g/day. However, these rates were all calculated on a per capita basis and were obtained from only two surveys conducted in the late 1960's (Market Facts Consumer Panel Survey) and early 1970's (NPD). Thus, these results have limited use for estimating consumption of shellfish in California.

Rupp et al. (1980) reported yearly amounts of seafood actually consumed by adults in the U.S. as 3.41 kg/yr for freshwater fish, 3.52 kg/yr for marine fish, and 3.06 kg/yr for shellfish. These values, which represent "per capita" rates for (adult) "consumers only," are roughly equivalent on an annual "per consumer" basis. These findings indicate that for those who consumed shellfish, the amount was only slightly less than the amounts of freshwater finfish and saltwater finfish consumed. Rupp and colleagues also reported that consumption rates for each type of seafood, *i.e.* freshwater, marine, or shellfish, varied by region, and the Pacific region was noted for greater consumption of crabs, oysters, and clams. In their analyses, the Pacific region had slightly higher average per capita consumption rates than the overall U.S. population (1.16 kg/yr compared to 1.01 kg/yr). The percentage of users was also slightly greater in the Pacific region (49.2% compared to 41.5%). However, there are few data to indicate whether portions of the population consume primarily shellfish alone or whether, and to what extent, shellfish are consumed in addition to finfish. Therefore, it is uncertain whether a rate that applies to shellfish consumption alone is appropriate. In addition, these rates do not distinguish sport-caught and commercial shellfish.

The Center for Food Safety and Applied Nutrition of the U.S. Food and Drug Administration (FDA) has issued a series of guidance documents addressing heavy metal contamination of shellfish. In this series, "consumer only" consumption rates for crustacean shellfish and

molluscan bivalves were presented. The values were derived from data obtained in a 14-day survey conducted by MRCA in 1988 and from analyses conducted by Pao et al. (1982) on the 1977-78 USDA NFCS dataset. However, these data were limited to only certain types of commercially available shellfish. Despite these limitations, FDA (1993) reported that for adult consumers, 18-44 years, the 14-day average intake of molluscan bivalves was 12 g/day, and the 90th percentile was 18 g/day. The 14-day average intake of crustacean shellfish by adult consumers (18-44 years) was 9 g/day and the 90th percentile was reported as 19 g/day. FDA (1993) indicated that these values could be used to model probable chronic or long-term exposure to contaminants. They also reported mean and 90th percentile values for acute or single-exposure intake rates for adults as 117 g/day and 227 g/day, respectively, for molluscan bivalves, and 67 g/day and 135 g/day, respectively, for crustacean shellfish.

Puffer et al. (1982) listed shellfish, principally crabs, mussels, and abalone, among the primary types of “fish” kept by sportfishers. They reported that three percent of the fishers that were interviewed obtained shellfish and that 97 percent of them consumed the catch. They calculated a median rate of consumption of shellfish of 10.0 g/day/person. Median consumption rates were similarly calculated for the other common species. However, the overall median rate of fish and shellfish consumption (36.9 g/day) determined from the data obtained in this survey represented the amount consumed on average of any type of seafood. There is no reason to assume that a shellfish consumer eats no other type of fish or consumes less on average than the amount indicated by the overall median rate.

Data obtained in the Santa Monica Bay study indicated that shellfish comprised a small percentage (5.7%) of total catch (based on the number caught). Few individuals who reported consumption of shellfish species were included in the calculations used to derive consumption rates in this survey. Landolt et al. (1985) found that the number of crabs (defined as shellfish) caught in the four bays surveyed in Puget Sound comprised less than three percent (of the total number caught) of the twenty most commonly taken species. However, squid (which were not considered in this study to be shellfish, but which are related to other shelled organisms) comprised 39% of the most common catch. These studies indicated that shellfish ranked among the most commonly caught types of seafood, but often comprised only a small percentage of total catch, and that regional preferences for favored species may exist and should be taken into account. Data are not available to indicate what portion of the population in California consumes shellfish, the percentage of consumers that eat a combination of fish and shellfish, whether some consumers eat only shellfish, or to estimate the average percentage of total intake comprised of shellfish. However, there is little reason to conclude that a sport fisher taking shellfish eats a different amount on average than a sport fisher eating finfish or a combination of fish and shellfish. Furthermore, although only a few shellfish consumers were included in the calculations of consumption rates, it may be reasonable to assume that the estimates of consumption derived from the Santa Monica Bay study would apply generally to sport fish consumers including consumption of both shellfish and finfish species.

In contrast, data on the consumption of crabs by crabbers along the New Jersey shore indicated relatively high rates of shellfish consumption, particularly compared to the estimated rates of consumption of fish by fishers in the same region. May and Burger (1996) reported average consumption of crabs to be 9.5 crabs per meal at an average frequency of 3.7 times per month, and assuming that each crab would provide 160 grams of edible muscle tissue, determined an average consumption rate of 187 g/day. The maximum reported intakes were 16 meals per month and 25 crabs per meal. More than 65 percent of the crabbers that were interviewed in this survey indicated that they caught at least three-fourths of the crabs that they ate. These results suggest that in some cases, the average rate of consumption of shellfish species may, in fact, considerably exceed estimated average rates of consumption of fish.

Clearly there is a need for more data on the consumption of shellfish. Exposure assessments, particularly those conducted in regions such as the Pacific coast or other coastal areas, where certain types of shellfish or other invertebrates are favored, would need to obtain region-specific data in order to fully address shellfish consumption as a component of total fish consumption. Until data are available to elucidate behavior patterns and consumption rates for shellfish species, it will be assumed that the estimated rates of consumption for California fishing populations can be applied to consumption of either fish or shellfish, or fish and shellfish combined.

C. Other Issues

1. Meal Or Portion Size

U.S. EPA (1992) stated that the most commonly reported portion size for the consumption of fish was eight ounces (227 g). Many studies have used the 8-oz portion size in assumptions used to calculate fish consumption rates (*e.g.* Connelly et al., 1990; Fiore et al., 1989). However, some studies have used other portion sizes. For example, in calculations performed by U.S. EPA (1993) based on data obtained in various studies (*e.g.*, Connelly et al., 1990) portion size was assumed to be approximately 5 oz (145 g).

Pao et al. (1982) reported the average and the distribution of the quantity consumed per eating occasion for the total survey consumer population and for 16 age/sex subgroups based on data from the 1977-78 NFCS. The average meal size for the total survey consumer population was found to be 117 g, or 4 oz. The median and 90th percentile values were 85 g (3 oz.) and 227 g (8 oz.), respectively. Meal sizes for finfish were slightly higher than for fish and shellfish in general. Average portion size for finfish was 145 g (5 oz.). Meal sizes tended to be smaller for children compared to adults and greater for men than for women, most likely reflecting differences in body weight. The mean meal size for fish and shellfish for adults ranged from 104 to 123 g (3.7 to 4.3 oz) for females and from 124 to 149 g (4.4 to 5.3 oz) for males. Average consumption rates of finfish ranged up to 191 g (6.7 oz) among males.

West et al. (1989a) determined fish meal size by asking respondents to estimate meal size relative to a picture of an eight-ounce portion of fish. If the amount reported was “less” than the

pictured meal, portion size was recorded as five ounces and if respondents reported “more” than the eight-ounce picture, portion size was considered to be ten ounces. However, the frequency of consumption of each portion size was not presented in the results.

In the fish consumption survey of four Native American tribes in the Columbia River basin, the average serving size for fish meals for adult consumers ranged from less than one to 24 ounces. More than half of the respondents reported an average fish meal size of eight ounces and the calculated mean serving size was 8.42 ounces (CRITFC, 1994).

May and Burger (1996) reported that the average serving size for fish meals eaten by fishers from three regions of the New Jersey coast ranged from 10.3 to 11.5 ounces per meal. They also reported that an average of 9.5 crabs were eaten per meal by crabbers in the same region. May and Burger assumed that each crab yielded approximately 160 grams of edible muscle tissue, resulting in an average serving size of 53.6 ounces of crab.

In summary, data on actual meal size are limited. Assumptions about portion sizes are inconsistent among fish and shellfish consumption studies, but typically range from four to eight ounces of fish and/or shellfish per meal. Similarly, actual meal or portion sizes, when reported, usually ranged from four to eight ounces. However, in one study, somewhat larger average portion sizes (up to 11.5 oz) were determined for consumption of fish, and a considerably greater average serving size (54 oz) was reported for consumption of crabs.

D. Recommendations for Selection of Appropriate Estimates or Default Values for the Consumption of Fish and Shellfish

In order to select the most appropriate estimates of consumption of fish and/or shellfish, it is essential to identify the purpose and use of these values as well as to determine the applicability and reliability of the study or studies from which the estimated rates are derived. For example, when fish consumption rates are to be used to conduct an exposure assessment for locally abundant pollutants only, a consumption rate that applies to sport fish consumption from the affected water bodies should be used. Additionally, in order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption rates that apply to people who actually consume sport fish and/or shellfish, rather than per capita estimates, should be used. Similarly, if consumption rates are to be used to develop water quality criteria, estimates which apply to the consumption of sport fish and/or shellfish from the water body of concern are appropriate. Per capita consumption rates derived for the general population (including nonconsumers) would not be appropriate for determining potential health risks from consumption of contaminated fish or shellfish and thus are not applicable to the development of water quality criteria for local water bodies.

In contrast, estimates of consumption of fish and/or shellfish from all sources may be appropriate in some circumstances. For example, if a risk assessment is conducted to evaluate exposure to a

chemical(s) of concern with a global distribution, such as methylmercury, then a rate for total fish consumption from all sources, including commercial and sport fish, is relevant.

1. Sport Fishing Populations in California

The Santa Monica Bay Seafood Consumption Study provides the best available dataset for estimating consumption of sport fish and shellfish in California. This study provided a distribution of consumption rates for the population fishing from Santa Monica Bay which reflects the range of values and the variability within the population. Consumption of sport fish and/or shellfish by populations in California can be described either by using the full distribution in a stochastic analysis or by using the median, mean, and an upper percentile intake rate from this distribution. Although this study applied to a population fishing from a marine water body, a similar distribution of consumption rates was determined from data obtained in Michigan on a population fishing from freshwater bodies. Thus, the default values derived from the Santa Monica Bay study can reasonably be applied to fishers using any productive water body in the state. Until reliable data become available which describe consumption of freshwater sport fish in California, it is recommended that the default values from the Santa Monica Bay study of 21 g/day for the median, 50 g/day for the mean, 107 g/day for the 90th percentile, and 161 g/day for the 95th percentile rate be used to estimate consumption from both marine and freshwater sources of sport fish and shellfish in California.

2. Sport Fishing Populations in Other Regions

Regional studies of sport fishing populations reported overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 g/day. These studies can provide default values for populations fishing in these regions and can be used to derive estimates for sport fishing populations in other regions where geographic and population characteristics are similar. However, the limitations of a given study as discussed in this document should be considered and factored into decisions about which default values are appropriate for use. Additionally, it is recommended that estimates for populations include at least a median, mean, and upper percentile rate (rather than a single value) to reflect the variability in consumption rates typical of sport fish consuming populations.

In some cases, an adequate dataset may not be available to represent the population in question. Because the Santa Monica Bay Seafood Consumption Study represents the most comprehensive and well-conducted study to date of sport fishing populations, the distribution of consumption rates or default values derived from this study can be used to represent other populations that consume sport fish and/or shellfish when locally specific data are not available or are not considered adequate.

3. Consumption Rates for Subpopulations

Consumption rates can vary among subpopulations by race or ethnicity, age, sex, income, fishing mode, geographic region, and other demographic variables. However, an evaluation of differences in average consumption rates for subpopulations showed that the differences, when they occurred, were less than an order of magnitude. The greatest differences in consumption rates for specific subpopulations were on the order of a maximum of five times greater when comparing the highest-consuming and lowest-consuming ethnic subpopulations in a survey. Additionally, average consumption rates for the highest consuming ethnic subgroups were approximately three times the overall mean rate for the survey population. These differences would contribute a relatively small amount of error in exposure assessments, if the appropriate rate for a particular subpopulation were not included (relative to the degree of uncertainty already inherent to risk assessment). Although every effort should be made to obtain the most relevant data and to adequately describe consumption by subpopulations of interest, in those cases where inadequate data are available for subpopulations suspected to have above-average consumption rates, upper level intake rates from a distributional analysis are likely to represent subgroups with above-average consumption.

VI. CONCLUSIONS

A number of factors contribute to the variability in reported fish consumption rates. As stated previously, how fish and/or shellfish are defined; how populations are defined; which population is targeted and how adequately the sample population represents the target population; the sources of fish and how they are defined, differentiated, and measured; the type of data collected and by which methods; the time period of the study; methods of data analysis and how researchers work with biases in the dataset; and other locally specific factors all contribute to variability in results.

Ideally, site-specific data that reflect the full distribution of consumption rates for the population of interest would be available. However, given time and resource constraints, exposure and risk assessors will have to look for the most relevant and reliable data sources for the populations of concern and make decisions based on the best available information at the time.

Given the information reviewed in this paper, the following conclusions can be drawn:

- 1) In order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption rates that apply to people who actually consume the fish and/or shellfish should be used. If consumption rates are to be used to develop water quality criteria, estimates which apply to the consumption of fish and/or shellfish from the water body of concern are appropriate. Per capita consumption rates derived for the general population (including nonconsumers) would not be appropriate for determining potential health risks from consumption of contaminated fish or shellfish and thus are not applicable to the development of water quality criteria for local water bodies. When fish consumption rates are to be used to conduct an exposure assessment for locally abundant pollutants only, a consumption rate that applies to sport fish consumption (by consumers) from the affected water bodies should be used. In contrast, if the chemical(s) of concern is one with a more global distribution, such as methylmercury, then a rate for total fish consumption from all sources, including commercial and sport fish, is relevant. Therefore, it is essential to identify the purpose and use of fish consumption rates as well as to determine the applicability of the study or studies selected to derive estimated rates for fish and shellfish consumption.
- 2) Per capita rates are estimates derived for the general population inclusive of both consumers and nonconsumers. Thus, per capita rates are primarily useful for trend analyses rather than representing actual consumption by consumers. Average per capita rates for fish and shellfish consumption for the general population derived from national surveys ranged from 12 to 17.9 g/day. Several analyses of data used to estimate per capita consumption of fish and shellfish found an increase of approximately 25 percent between 1970 and the early 1990's, indicating that the U.S. population as a whole consumed more fish in more recent years.
- 3) "Consumer only" consumption rates are preferable to per capita rates for use in describing actual consumption of fish and shellfish in the U.S. The only overall national mean rate currently

published and applicable to all consumers of fish and shellfish combined is 48 g/day. This value may be a minimum estimate as it does not include fish and shellfish in mixed dishes.

Additionally, this value was derived from a study conducted nearly twenty years ago, in the mid-1970's. Unpublished results from a more recent national survey determined an estimated mean rate of 100 g/day for consumers of fish and/or shellfish including mixed dishes. However, data for "consumers only" from national surveys are limited because the reporting period typically covered only three days, and frequency of consumption was not determined. Therefore, the results may not characterize long-term consumption rates for consumers. Additionally, national studies that have been conducted thus far were not intended to address consumption of sport fish and shellfish. Thus, the results of these surveys are applicable mainly to consumption of commercial fish and shellfish and are not suitable for characterizing consumption by fishers or other consumers of sport fish and shellfish.

4) Regional studies of sport fishing populations reported overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 g/day. Additionally, the overall mean rates for total fish consumption calculated from the studies that targeted fishing populations (and reported on consumption of both sport and commercial fish and shellfish) ranged from 16.1 to 61.3 g/day. These studies indicated that sport fishers consumed both sport fish and commercially available species. Estimates of average consumption rates for commercially available species added approximately 8-20 g/day (and up to 42 g/day) to the average consumption rates for sport-caught fish. The consumption studies of fishing populations can be used to derive estimates for sport fishing populations in regions where geographic and population characteristics are similar, provided that the limitations of a given study are considered. Additionally, estimates for populations should include at least a median, mean, and upper percentile rate to reflect the variability in consumption rates typical of sport fish consuming populations.

5) The 6.5 g/day default value originally developed by U.S. EPA for consumption of fish and shellfish from estuarine and freshwaters by the general population has been adopted by other agencies and applied in innumerable instances inappropriately, without an adequate understanding of its derivation and applicability. Consequently, the widespread use of 6.5 g/day as a default value for fish consumption, particularly for sport fishers, has been unjustified and inappropriate. The use of this per capita estimate to represent actual consumption by consumers of sport fish and/or to derive water quality criteria which are intended to protect consumers of fish obtained from these water bodies is indefensible.

6) Difficulties in defining and evaluating subsistence fishers have resulted in limited information pertaining to consumption rates for subsistence populations. A number of subpopulations shown in some studies to be high-consuming groups (*e.g.*, Native Americans and some Asian populations) may be underrepresented in consumption surveys, especially if the sampling frame is based on fish license holders. Language and literacy issues may also be barriers to survey participation. A few distributional datasets are currently available for sport fishing populations believed to either represent or include subsistence fishers. The CRITFC (1994) study of Native American subsistence fishers reported a mean consumption rate of 63.2 g/day and a rate of 170

g/day at the 95th percentile. In locations where exceptionally high consumption by subsistence populations or other people is expected, obtaining data for the subpopulation of interest would be preferable to the use of default values. Locally applicable data would be particularly useful in areas where potential subsistence populations have easy free access to productive water bodies. However, in the absence of local data on subsistence populations, use of an upper level intake rate in exposure assessments such as the 95th percentile from a distributional analysis of fishing populations (*e.g.*, the Santa Monica Bay Seafood Consumption Study) would encompass consumption rates for individuals reporting above-average consumption and may account for consumption by subsistence fishers within these populations.

7) Consumption rates can vary by race or ethnicity, income, fishing mode, region of the country, and other demographic variables. Per capita studies and regional surveys of fishers showed differences in the type of species preferred for consumption in certain regions of the U.S. A number of studies have demonstrated trends in higher rates of fish consumption related to factors such as race or ethnicity. These studies showed that fish consumption rates were higher for certain subpopulations including some Asian populations, Blacks, Native Americans, and other minority groups, although the trends were not consistent across studies. Survey methodologies and the definitions of subpopulations differed among surveys so that comparisons among studies are difficult. The results of these studies showed that careful definition of ethnic groups is important to the outcome, particularly for “Asian” populations as a result of the variability in consumption of fish and shellfish among these different cultures. Some studies also found differences in the patterns of fish consumption and fishing behavior among subgroups. The interaction of demographic variables and region-specific factors must be taken into account to fully understand potential differences among subpopulations. However, reported mean consumption rates for ethnic subpopulations differed at most by five times and the highest-consuming ethnic subpopulation had an average consumption rate that was approximately three times higher than the overall average rate for the study population. Higher-consuming ethnic subpopulations and other high-end consumers are likely to be represented by the upper percentile consumption rates (such as the 95th percentile) derived from a distributional analysis.

8) Studies that differentiated fish consumption rates (g/day) by age and sex showed that, generally, males consumed more than females, and the amount of fish consumed increased with age. However, few of these studies accounted for differences in body weight in their analyses. To some extent, the differences are likely to be attributable to differences in body weight. Exposure assessments should consider body weight as a parameter and use sex and age-specific consumption rates, when available, or adjust for differences in body weight when evaluating subsets of the population. Additionally, there is limited evidence that elderly fishers in certain regions and some subpopulations in which a combination of demographic variables interact (*i.e.* ethnicity and age) consume fish and/or shellfish at rates that exceed the average for adult sport fish consumers. In these studies, elderly fishers consumed fish at mean rates that were two to three times greater than the overall average rate. Because of these demographic differences, region-specific data are preferred when available. In the absence of actual data, higher

consuming subgroups are likely to be included within the upper percentile consumption rates derived from a distributional analysis.

9) The available data suggest that consumption rates for sport-caught marine and estuarine fish tend to be comparable to those for sport-caught freshwater fish. Additional data are needed to evaluate the potential for differences in consumption of fish obtained from water bodies in specific regions of the U.S. where variables such as access and availability of fish and/or shellfish may differ.

10) Consumption of sport fish by populations in California can be described by the consumption rates determined in the Santa Monica Bay Seafood Consumption Study of 21 g/day, 50 g/day, 107 g/day, and 161 g/day for the median, mean, 90th and 95th percentile rates, respectively. Few studies have specifically addressed rates of consumption of commercial fish and shellfish in California. However, several studies have indicated that total consumption by fishers is greater than sport fish consumption, and suggested that the difference in amount between sport and total consumption ranges from approximately 8 to 42 g/day. Adding an additional amount to the estimated consumption rate for sport fish and shellfish (at least 8 to 20 g/day, on average, of commercially available species) will account for supplemental consumption of commercial species, or total consumption, by sport fishing populations in California. Additionally, national estimates for consumers (particularly those derived from the most current studies, once the results are available) can be used to describe consumption by the general population in California that consumes only commercial species, although the results may not adequately characterize “typical” consumption rates for consumers over time. Insufficient data are available to estimate consumption rates for shellfish. The rates provided for sport fish consumption in the Santa Monica Bay Seafood Consumption Study may encompass consumption of shellfish species by those people who catch shellfish as opposed to finfish.

11) The Santa Monica Bay Seafood Consumption Study represents the most comprehensive and well-conducted study to date of sport fishing populations. Although this study sampled fishers using a marine water body, the similarity in results between this dataset and the analysis of data on freshwater fishers in Michigan by Murray and Burmaster (1994) suggests that the results are applicable to sport fish consuming populations in any region where geographic and population characteristics are similar. Thus, the distribution of consumption rates derived from the Santa Monica Bay dataset can be used as default values when locally specific data are not available (or appear to be inadequate).

12) Data on meal or portion size are limited. Assumptions about portion sizes are inconsistent among fish and shellfish consumption studies, but typically range from four to eight ounces of fish and/or shellfish per meal. Actual mean meal or portion sizes, when reported, usually ranged from four to eight ounces. More data on meal size and the frequency of consumption of fish and/or shellfish can be used to improve the accuracy of estimates of consumption rates.

13) The results of distributional analyses of intake rates reflect the large amount of variability within populations consuming fish and shellfish. Consumption rates within a population can best be represented by distributional analyses rather than single point estimates. Using a stochastic analysis or at least the median, mean, and an upper percentile rate of intake derived from a distributional analysis will allow a better characterization of consumption in a population and the variability within that population.

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APPENDIX I: GLOSSARY

angler - one who fishes with hook and line (note that this is the technically correct definition, however, several studies have used this term to denote “fishers”)

aquatic - from or living in a water body, including both marine and freshwater

bivalves - aquatic animals (belonging to the phylum Mollusca and the class Bivalvia) whose body is enclosed in a shell consisting of two valves, *e.g.*, clams, mussels, oysters, scallops

cephalopods - aquatic animals (belonging to the phylum Mollusca and the class Cephalopoda) having tentacles attached to the head, *e.g.*, octopus, squid, cuttlefish, nautilus

commercial fisher - an individual who derives income from catching and selling living aquatic resources

creel survey - on-site interviews with fishers to obtain information such as species caught, number, length, and weight of catch, location, etc., typically for use by fisheries managers; may or may not include information on consumption

crustaceans - primarily aquatic animals (belonging to the phylum Arthropoda and the subphylum Crustacea) typically having a body covered by a jointed exoskeleton, *e.g.*, shrimps, crabs, lobster

echinoderms - marine animals (belonging to the phylum Echinodermata) typically having pentaradial symmetry (in adult forms) and a calcareous skeleton, often with projecting spines, *e.g.*, sea urchins, sand dollars, sea cucumbers, sea stars

estuarine - from an estuary, *i.e.*, a partly enclosed water body, such as an inlet of the ocean or the mouth of a river where it meets the ocean, that contains brackish water (a mixture of salty and freshwater) such as San Francisco Bay

finfish - fish; a term that is usually applied to the consumption of fish as opposed to shellfish

fish - any of various aquatic animals (belonging to the subphylum Vertebrata) having gills, commonly fins, and bodies usually but not always covered by scales, including those having bony skeletons (bony fishes) and more primitive forms with cartilaginous skeletons (lampreys; hagfishes; and sharks, skates, and rays)

fisher - one who fishes for any type of seafood by any method, inclusive of hook and line and other methods of catching seafood

fish in hand - fish and/or shellfish that a fisher has caught and which he/she has at the time of being interviewed (in a creel survey)

freshwater - water bodies including lakes, ponds, rivers, and streams that contain water with relatively low salinity, i.e. less than 0.5 ppt; species inhabiting freshwater bodies

game fish - sport fish that are caught for food

gastropods - aquatic and terrestrial animals (belonging to the phylum Mollusca and the class Gastropoda) typically having an asymmetrical spiral shell that (when present) is used as a protective retreat, *e.g.*, snails, limpets, slugs, abalone

marine - from, or living in, the ocean; saltwater, with a salinity of approximately 35 ppt

mollusks - members of the highly diverse invertebrate phylum Mollusca, including soft unsegmented animals usually protected by a shell and having a muscular foot for locomotion; includes the gastropods (snails), bivalves (clams, oysters), and cephalopods (squids, octopus)

noncommercial fisher - one who fishes for recreation and/or home consumption, synonymous with recreational fisher, sport fisher

recreational fisher - one who fishes primarily for recreational purposes; recreational catch is used primarily for home consumption, synonymous with noncommercial fisher, sport fisher

seafood - aquatic organisms that are consumed, including mainly fish and shellfish, and less frequently, other invertebrate animals or plants or marine mammals

self-caught fish - fish that are caught by a sport fisher as opposed to purchased commercially, synonymous with sport, sport-caught, recreationally caught, and noncommercial fish

shellfish - aquatic invertebrate animals having a shell or exoskeleton, the term usually used in the context of food, including species belonging to the following taxa (some of which have evolved such that the shell has become internal and/or reduced, or has disappeared entirely): 1) mollusks, including bivalves (*e.g.*, clams, oysters, mussels, scallops), gastropods (*e.g.*, snails, limpets, abalone), and cephalopods (*e.g.*, squid, octopods); 2) crustaceans (*e.g.*, crabs, shrimps, lobsters); and 3) echinoderms (*e.g.*, sea urchins, sea cucumbers)

sport fish - fish that are caught by a sport fisher as opposed to purchased or caught commercially, synonymous with sport-caught, self-caught, recreationally caught, and noncommercial fish

sport fisher - one who fishes, by any method, for recreation, synonymous with recreational fisher, noncommercial fisher

subsistence fisher - one who fishes for food, for economic and/or cultural reasons, and for whom the fish and/or shellfish caught is a major source of protein in the diet

APPENDIX II: TABLES